Installation & Maintenance Manual **Slip Ring Machines**

October 2006 AMK 400-500

ABB SACE

Safety Instructions

AMA, AMB, AMC, AMH, AMK, AML, HXR

1 General

General safety regulations, specific agreements made for each work site and safety precautions shown in this document must be observed at all times.

2 Intended use

Electric machines have dangerous live and rotating parts and may have hot surfaces. All operations serving transport, storage, installation, connection, commissioning, operation and maintenance shall be carried out by responsible skilled persons (in conformity with EN 50 110-1 / DIN VDE 0105 / IEC 60364). Improper handling may cause serious personal injury and damage to property. Danger!

These machines are intended for industrial and commercial installations as components as defined in the Machinery Directive (MD) 89/392/EEC. Commissioning is prohibited until conformity of the end product with this directive has been established (follow particular local safety and installation rules as e.g. EN 60204).

These machines comply with the harmonized series of standards EN 60034 / DIN VDE 0530. Their use in hazardous areas is prohibited unless they are expressly designed for such use (follow additional instructions).

On no account, use degrees of protection ≤ IP 23 outdoors. Air-cooled models are typically designed for ambient temperatures of -20°C up to +40°C and altitudes of ≤ 1000 m above sea level. Ambient temperature for air-/water-cooled models should be not less than +5°C (for sleeve-bearing machines, see manufacturer's documentation). By all means, take note of deviating information on the rating plate. Field conditions must conform to all rating plate markings.

3 Transport, storage

Immediately report damage established after delivery to transport company. Stop commissioning, if necessary. Lifting eyes are dimensioned for the weight of the machine, do not apply extra loads. Ensure the use of correct lifting eyes. If necessary, use suitable, adequately dimensioned means of transport (e.g. rope guides). Remove shipping braces (e.g. bearing locks, vibration dampers) before commissioning. Store them for further use.

When storing machines, make sure of dry, dust and vibration free location (danger of bearing damage at rest). Measure insulation resistance before commissioning. At values of ≤ 1kΩ per volt of rated voltage, dry winding. Follow manufacturer's instructions.

4 Installation

Make sure of even support, solid foot or flange mounting and exact alignment in case of direct coupling. Avoid resonances with rotational frequency and double mains frequency as a result of assembly. Turn rotor and listen for abnormal slip noises. Check direction of rotation in uncoupled state.

Follow manufacturer's instructions when mounting or removing couplings or other drive elements and cover them with a touch guard. For trial run without output elements, lock or remove the shaft end key. Avoid excessive radial and axial bearing loads (note manufacturer's documentation). The balance of the machine is indicated as H = Half and F = Full key. With half-key models, the coupling too, must be half-key balanced. In case of protruding, visible part of the shaft end key, establish mechanical balance.

Make necessary ventilation and cooling system connections. The ventilation must not be obstructed and the exhaust air, also of neighbouring sets, not taken in directly.

5 Electrical connection

All operations must be carried out only by skilled persons on the machine at rest. Before starting work, the following safety rules must be strictly applied:

- De-energize!
- Provide safeguard against reclosing!
- Verify safe isolation from supply!
- Connect to earth and short!
- Cover or provide barriers against neighbouring live parts!
- De-energize auxiliary circuits (e.g. anti-condensation heating)!

Exceeding of limit values of zone A in EN 60034-1 / DIN VDE 0530-1 - voltage ± 5%, frequency ± 2%, waveform and symmetry - leads to higher temperature rise and affects the electromagnetic compatibility. Note rating plate markings and connection diagram in the terminal box.
The connection must be so made that permanent safe electrical connection is maintained. Use appropriate cable terminals. Establish and maintain safe equipotential bonding.

The clearances between uninsulated live parts and between such parts and earth must not be below the values of appropriate standards and values possibly given in manufacturer's documentation.

No presence of foreign bodies, dirt or moisture is allowed in the terminal box. Close unused cable entrance holes and the box itself in a dust- and watertight manner. Lock the key when the machine is run without coupling. For machines with accessories, check satisfactory functioning of these before commissioning.

The proper installation (e.g. segregation of signal and power lines, screened cables etc.) lies within the installer's responsibility.

6 Operation

Vibration severity in the "satisfactory" range (V_{rms} ≤ 4.5 mm/s) according to ISO 3945 is acceptable in coupled-mode operation. In case of deviations from normal operation - e.g. elevated temperature, noises, vibrations - disconnect machine, if in doubt. Establish cause and consult manufacturer, if necessary.

Do not defeat protective devices, not even in trial run. In case of heavy dirt deposits, clean cooling system at regular intervals. Open closed condensate drain holes from time to time.

Grease the bearings during commissioning before start-up. Regrease antifriction bearings while the machine is running. Follow instructions on lubrication plate. Use right kind of grease. In case of sleeve-bearing machines, observe time-limit for oil-change and if equipped with oil supply system make sure the system is working.

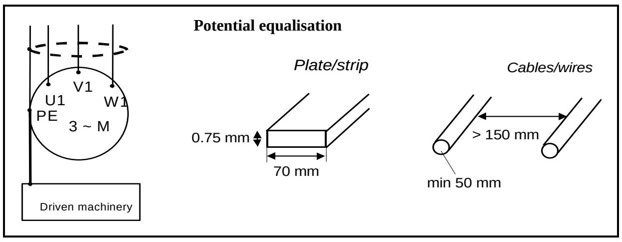
7 Maintenance and servicing

Follow manufacturer's operating instructions. For further details, see the comprehensive User´s Manual. Preserve these safety instructions!

8 Frequency converter

In frequency converter applications motor frame external earthing must be used for equalising the potential between the motor frame and the driven machine, unless the two machines are mounted on the same metallic base. For motor frame sizes above IEC 280, use 0.75 x 70 mm flat conductor or at least two 50 mm² round conductors. The distance of the round conductors must be at least 150 mm from each other.

This arrangement has no electrical safety function; the purpose is to equalise the potentials. When the motor and the gearbox are mounted on a common steel fundament, no potential equalisation is required.



To comply with EMC-requirements, use only cables and connectors approved for this purpose. (See instruction for frequency converters.)

Additional Safety Instructions for Electrical Motors for Hazardous Areas

Note

These instructions must be followed to ensure safe and proper installation, operation and maintenance of the motor. They should be brought to the attention of anyone who installs, operates or maintains this equipment. Ignoring the instruction may invalidate the warranty.

Warning

Motors for hazardous areas are specially designed to comply with official regulations concerning the risk of explosion. If improperly used, badly connected, or alter, no matter how minor, their reliability could be in doubt.

Standards relating to the connection and use of electrical apparatus in hazardous areas must be taken into consideration, especially national standards for installation. Only trained personnel familiar with these standards should handle this type of apparatus.

Declaration of Conformity

All ABB machines comply with:

- The Low Voltage Directive 73/23/EEC amended by Directive 93/68/EEC
- EMC Directive 89/336/EEC, amended by Directives 92/31/EEC and 93/68/EEC
- Certificate of Incorporation with respect to the Machinery Directive 89/392/EEC, amended by Directives 91/368/EEC, 93/44/EEC and 93/68/EEC
- All ABB Ex-machines, which have a CE-mark on the rating plate comply with the ATEX Directive 94/9/EC

Validity

These instructions are valid for the following ABB's electrical motor types, when the machine is used in explosive atmospheres.

Non-sparking Ex nA, Ex N, EEx nA
- AMA Induction Machines, sizes 315 to 500
- AMB Induction Machines, sizes 560 to 710
- HXR Induction Machines, sizes 315 to 560
- AMC Induction Machines, sizes 800 to 1000

Increased safety EEx e, Ex e
- AMA Induction Machines, sizes 315 to 500
- AMB Induction Machines, sizes 560 to 710
- HXR Induction Machines, sizes 315 to 560
- AMC Induction Machines, sizes 800 to 1000

Pressurisation EEx pe, Ex pe, EEx p, Ex p
- AMA Induction Machines, sizes 315 to 500
- AMB Induction Machines, sizes 560 to 710
- HXR Induction Machines, sizes 315 to 560
- AMC Induction Machines, sizes 800 to 1000

Dust Ignition Protection (DIP)
- AMA Induction Machines, sizes 315 to 500
- AMB Induction Machines, sizes 560 to 710
- HXR Induction Machines, sizes 315 to 560
- AMC Induction Machines, sizes 800 to 1000

(Additional information may be required for some machine types used in special applications or with special design.)

Conformity

As well as conforming to the standards relating to mechanical and electrical characteristics, motors designed for explosive atmospheres must also conform to the following IEC or CENELEC standards:

EN 50014;	General norm concerning explosion-proof material.
EN 50016;	Std. concerning EEx p protection
EN 50019;	Std. concerning EEx e protection
EN 50021;	Std. concerning EEx nA protection
EN 50281-1-1	Std. concerning Dust Ignition Protection
IEC 60079-0;	Std. concerning General Requirements for Explosive Atmospheres
IEC 60079-2;	Std. concerning Ex p protection
IEC 60079-7;	Std. concerning Ex e protection
IEC 60079-15;	Std. concerning Ex nA protection
IEC 1241-1-1	Std. concerning Dust Ignition Protection
BS 5000:16;	Std. concerning Ex N protection

ABB machines (valid only for group II) can be installed in areas corresponding to following marking:

Zone (IEC)	Category (EN)	Marking
1	2	EEx p, EEx pe ,EEx e Ex p, Ex pe ,Ex e
2	3	Ex nA ,Ex N, EEx nA

Atmosphere (EN);

G – explosive atmosphere caused by gases

D – explosive atmosphere caused by dust

Reception check

- Immediately upon receipt check the machine for external damage and if found, inform the forwarding agent without delay.
- Check all rating plate data, especially voltage, winding connection (star or delta), category, type of protection and temperature marking.

Notice following rules during any operations!

Warning !

Disconnect and lock out before working on the machine or the driven equipment. Ensure no explosive atmosphere is present while the work is in progress.

Starting and Re-starting

- The maximum number of the sequential starts has been declared in machine's technical documents.
- The new starting sequence is allowed after the machine has cooled to the ambient temperature (-> cold starts) or to operating temperature (-> warm starts).

Earthing and Equipotentialing

- Check before starting that all earthing and equipotentialing couplings are effectively connected.
- Do not remove any earthing or equipotentialing cables, which has been assembled by the manufacturer.

Clearances, creepage distances and separations

- Do not make any removal or adjustment in terminal boxes, which could decrease clearances or creepage distances between any parts.
- Do not install any new equipment to terminal boxes without asking for advises from ABB.
- Be sure that air gap between rotor and stator is measured after any maintenance for the rotor or bearings. The air gap shall be the same in any point between stator and rotor.
- Centralise the fan to the centre of the fanhood or the air guide after any maintenance. The clearance shall be at least 1% of the maximum diameter of the fan and in accordance with standards.

Connections in terminal boxes

- All connections in main terminal boxes must be made with Ex-approved connectors, which are delivered with the machine by the manufacturer. In other cases ask an advice from ABB.
- All connections, in auxiliary terminal boxes, as marked intrinsically safe circuits (Ex i) must be connected to proper safety barriers.

Note !

If there are any conflicts between this instruction and user manual, this document is prevailing.

Chapter 1 - Introduction

Chapter 1 - Introduction

1 General

This User´s Manual applies to slip ring machines of the type AMK made by ABB Induction Machines.

The information may sometimes be of a general nature and applicable to the various machines. Where a conflict exists between the contents herein and the actual machinery supplied, the user must either make an informed engineering judgement as to a course of action or, if any doubt exists, contact ABB.

Note! To avoid accidents, safety measures and devices required at the installation site must be in accordance with the instructions and regulations stipulated for safety at work. This applies to general safety regulations of the country in question, specific agreements made for each work site and safety instructions included in this manual.

2 Documentation

2.1 About this manual

The manual is based on 12 Chapters:

- Chapters 1-9: Machine related information from transport and storage to maintenance and repair.
- Chapter 10: Checklists to help operating the machine. Lists should be kept for reference during maintenance and trouble-shooting.
- Chapter 11: Trouble-shooting sheets to help inspectioning and trouble-shooting the machine.
- Chapter 12: Machine related drawings and additional information e.g. bearing construction and foundation instruction.

2.2 Documentation of the machine

The manual is delivered with each machine and is located in a plastic cover on the machine frame.

Each machine is supplied with a final dimension drawing and electrical connection diagram showing information on the following (as applicable):

- Mounting and outline dimensions
- Weight and load on foundation
- Location of lifting eyes
- Instrumentation
- Bearing oil requirements
- Main and auxiliary connections.

Note! Some customer specific items may not be included in this manual or the machine delivery. Additional documentation should be requested.

2.3 Documentation of starting, speed control and other equipment

This manual does not include any information about starting or speed control equipment (e.g. liquid coupling, control rheostat, cascade drive). This information is performed according to each equipment manual.

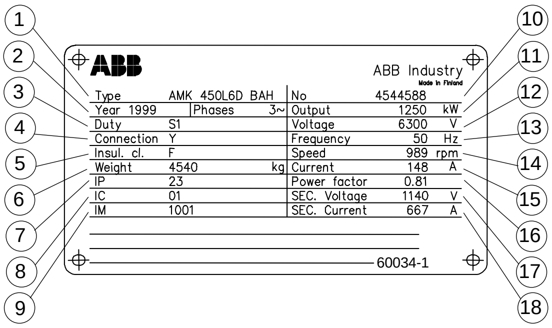
3 Machine

3.1 Serial number of the machine

Each machine is identified with a serial number. It is stamped on the rating plate and machine frame.

3.2 Rating and lubrication plate

A rating plate is fixed to the machine frame. It shows the most important electrical data and identification information (Figure 1).



1 Type designation	10 Serial number
2 Year of manufacture	11 Output in kW
3 Duty	12 Stator voltage
4 Type of connection	13 Frequency
5 Insulation class	14 Rotating speed
6 Machine weight in kg	15 Stator current
7 Degree of protection	16 Power factor (cosϕ)
8 Type of cooling	17 Rotor voltage
9 Mounting arrangement	18 Rotor current

Fig. 1. Standard rating plate (IEC version).

A lubrication plate is also fixed to the machine frame. It shows the type of the bearings and lubrication information.

3.3 Direction of rotation

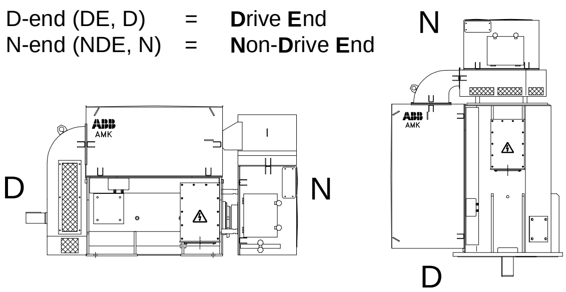
Arrow plate on the machine frame indicates the direction of rotation. The machine should be operated only in the direction(s) of the arrow. (Figure 2).

Clockwise Counter-clockwise Bi-directional

Fig. 2. Arrow plates.

3.4 Mounting and machine definitions

In this manual mounting arrangements and machine ends are presented as in Figure 3.



IM 1001
horizontal foot mounting

IM 4011
vertical flange mounting

Fig. 3. Mounting arrangements and machine ends.

3.5 Normal operating conditions

Each machine is individually designed and manufactured to operate in normal or abnormal operation conditions according to IEC or NEMA standard, customer specification and internal standards of ABB.

Normal operating conditions:

- Max ambient temperature +40°C (+104 °F).
- Max operating height 1000 m (3280 ft) above sea level.
- Foundation shall be free from external vibration.
- Surrounding air shall be free of dust, salt and corrosive gases.

The deviating ambient temperature and operating height is stamped on the rating plate. Other deviations agreed between the Customer and ABB are informed on the sales documentation.

3.6 Intended use

Electric machines have dangerous live and rotating parts and may have hot surfaces. All operations serving transport, storage, installation, connection, commissioning, operation and maintenance shall be carried out by responsible skilled persons (in conformity with EN 50 110-1 / DIN VDE 0105 / IEC 60364). Improper handling may cause serious personal injury and damage to property.

These machines are intended for industrial and commercial installations as components as defined in the Machinery Directive (MD) 89/392/EEC. Commissioning is prohibited until conformity of the end product with this directive has been established (follow particular local safety and installation rules as e.g. EN 60204).

These machines comply with the harmonized series of standards EN 60034 / DIN VDE 0530. Their use in hazardous areas is prohibited unless they are expressly designed for such use (follow additional instructions).

3.7 AMK machines type

AMK machines are based on a modular construction. They are available in horizontal and vertical mounting types and the standard shaft heights are 400, 450 and 500 mm (respectively in inches). Machines are weather protected or totally enclosed equipped with air-to-air or air-to-water heat exchanger (Figures 4, 5 and 6).

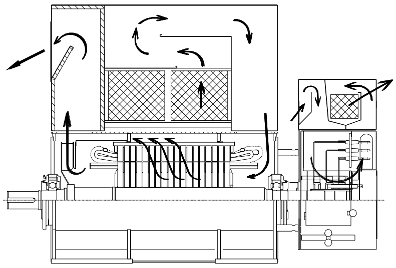


Fig. 4. Weather protected machine IC01 IP23 / WP-I, IC01 IPW24 / WP-II.

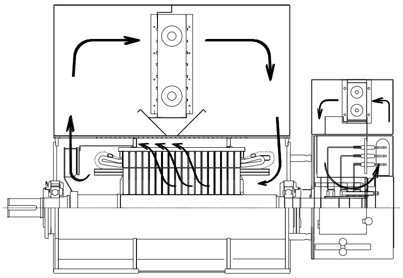


Fig. 5. Air-to-water cooled machine IC81W IP55 / TEWAC.

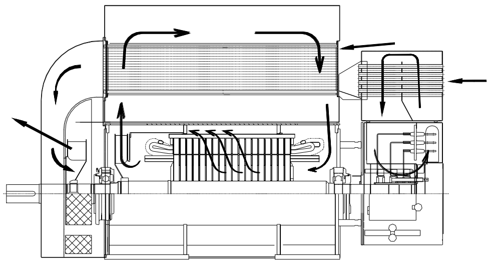


Fig. 6. Air-to-air cooled machine IC611 IP55 / TEAAC.

AMK machines cover the power range 180-2500 kW at 50 Hz, 250-4000 HP at 60 Hz and the speed range 500-1500 rpm and 600-1800 rpm respectively. Adjustable speed is also available. The voltage range cover from 380-11500 V (AC).

The slip ring unit, that locates always at the N-end, is equipped with a permanent contact or brush lifting type slip ring unit. The permanent contact type unit has a similar heat exchanger or protective cover as that of the machine. The brush lifting type unit is always totally enclosed and does not require any heat exchanger.

The purpose of the slip ring gear is to allow the machine to start with an adjustable and controllable amount of current and/or torque and run the machine with the rotor winding short circuited without brush wear.

4 Limitation of liability

In no event shall ABB be liable for direct, indirect, special, incidental or consequential damages of any nature or kind arising from the use of this document or any hardware described in this document.

ABB`s warranty covers manufacturing or material defect. It does not cover the damage caused by improper storage conditions, incorrect installation or operating against specifications. General conditions are defined according to Orgalime S92 specification.

Note! ABB`s warranty is not valid, if operation conditions, supply or load are changed inappropriately during machine's lifetime.

Warranty will remain valid only if proposed amendments in the construction or repair work to the machine are accepted by an approval from the ABB office / supplier factory.

Local ABB office may hold different warranty details, which are specified in the sales terms, conditions or warranty terms.

If you have any questions, please contact your local ABB representative or the factory:

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Chapter 2 - Transport and Storage

Chapter 2 - Transport and Storage

1 Protective measures prior to transport

The following protective measures are made before delivery at the factory:

- Machines with cylindrical roller and sleeve bearings are provided with a bearing locking device.
- Ball and roller bearings are greased with ESSO/EXXON UNIREX N3 or MOBILUX EP2.
- Sleeve bearings are bathed in oil and drained after that. Oil tubes are plugged.
- Air-to-water coolers are drained and water tubes are plugged.
- Blank metal surfaces (e.g. shaft extensions) are protected with an anti-corrosive coating.

2 Packages and lifting

Before the machine is lifted, ensure that suitable lifting equipment is available and personnel is familiar with lifting work. The weight of the machine is shown on the rating plate, dimension drawing and packing list.

Note! Each machine has strong lifting eye(s) to carry the load of the machine. Do not apply extra load or confuse them to other lifting lugs that are only to help service personnel to dismantle/ assemble the machine.

2.1 Unpacked machine

The machine should always be lifted by crane from the lifting eye(s) on the frame of the machine (Figures 1 and 2). The machine should never be lifted by forklift truck from the bottom.

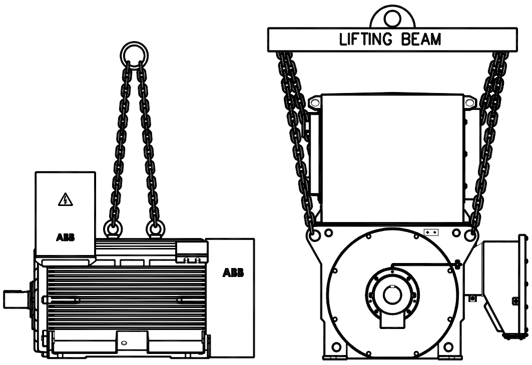

Fig. 1. Lifting of the horizontal machines.

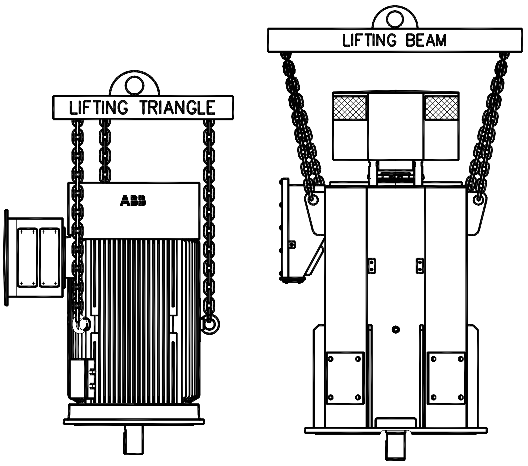

Fig. 2. Lifting of the vertical machines.

Note! Machines with upper cover, fan cover or slip ring unit should be lifted with a proper lifting beam or lifting triangle to prevent damaging these constructions.

Vertical mounting rib cooled machines may have turnable lifting eyes for lifting and turning the machine. Turning from vertical to horizontal position, or vice versa, is shown in Figure 3. Avoid damaging the painting or any parts during the procedure. Remove/install the bearing locking device when the machine is in vertical position.

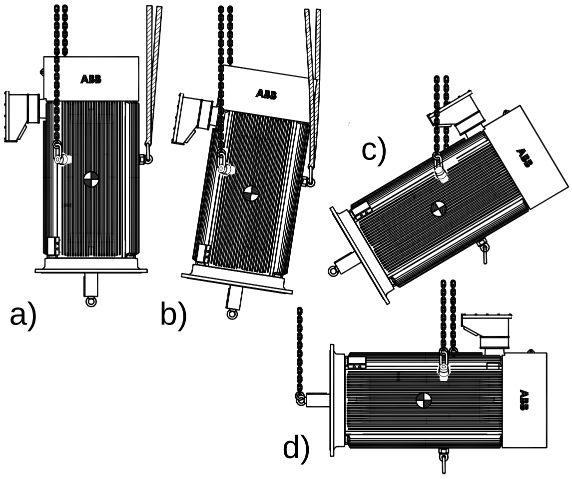

Fig. 3. Machine with turnable lifting eyes: lifting and turning.

2.2 Machine on pallet

The machine on a pallet should be lifted by crane from the lifting eye(s) (Figures 1 and 2) on the frame of the machine or by forklift truck from the bottom of the pallet. The machine is fixed to the pallet with bolts.

2.3 Machine in ocean freight package

The package should be lifted by forklift truck from the bottom or by crane with lifting slings. The sling positions are painted to the package (Figure 4).

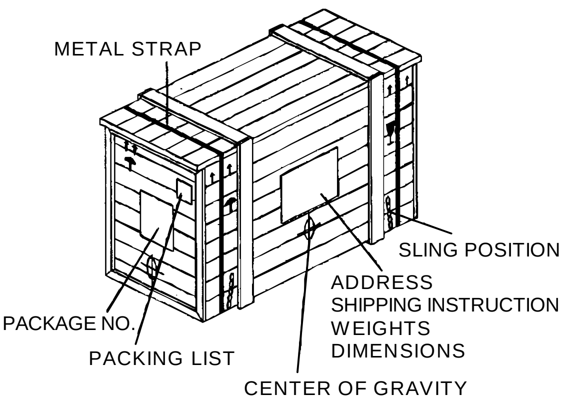

Fig. 4. Ocean freight package.

3 Checks

3.1 Check on arrival

When the transport company delivers the machine to the customer, the responsibility for the handling passes to the customer or other party. If damage has occurred during transportation do at least the following:

- Photograph all damage, including damage in the transportation box.
- Report any transport damage within one week after arrival, if the transport insurance is to be claimed. Check evidence of careless handling and report immediately to the transport company and the supplier. Use Checklist 1 in Chapter “Checklists”.

3.2 Check on unpacking

After the package has been removed, check that the machine is not damaged and all accessories are included. Report immediately to the supplier, if there is any damage, suspect of damage or if components are missing. Use Checklist 1 in Chapter “Checklists”.

4 Storage

4.1 Storage conditions

Machines with their associated control enclosures are stored in their original containers in a proper warehouse.

The storage warehouse should be clean, dry and ventilated. Corrosive gases, dust, shocks or vibration are not allowed. Protect the machine also against insects and vermin such as termites and rodents.

The storage temperature should be from 10°C to 50°C (from 50°F to 120°F) with a maximum relative humidity of 75 %.

4.2 Short term storage (less than 2 months)

A machine that is not installed immediately should not be left without supervision or protective precautions. Obey the following paragraphs and Checklist 2 in Chapter “Checklists”.

If the machine is temporarily left outdoors or in an open hall, cover it with tarpaulins. Leave space for ventilation between the machine or machine package and tarpaulins. Protect the machine or package also against ground damp by placing it on battens or boards.

If relative humidity is higher than 75 %, turn the anti-condensation heater on. To prevent condensation of moisture, keep the machine 5°C (9°F) above the dew point of the ambient air. Check periodically that the heater is operating.

If anti-condensation heater is not fitted, apply an alternative method of heating. Instead of heating, the machine can be protected from humidity by using moisture absorbing material, such as Silica-Gel.

If shocks or vibration is present or may occur later, isolate the machine by placing rubber blocks (fit for the purpose) under the feet.

4.3 Long term storage (over 2 months)

In addition to the measures described with short term storage, the following should be applied.

1. Measure the insulation resistance every three months. The lowest rated value for insulation resistance test at 40°C (104°F) is 40 MΩ [megaohms] (IEEE 43-1974, Recommended practice for testing insulation resistance of rotating machines).
2. Measure the winding temperature (Pt-100) every three months.
3. Check the condition of anti-corrosive coating on blank metal surfaces (e.g. shaft extensions) every three months. If any corrosion is observed, remove it with a fine emery cloth and perform the treatment again.
4. Check the condition of painted surfaces every three months. If rust is observed, remove it and apply a coat of paint again.
5. Arrange small ventilation openings when the machine is stored in a wooden box. Protect them against water, insects and vermin.

4.3.1 Antifriction bearings

Apply also the following measures:

1. Turn the rotor 10 revolutions every two months to keep the antifriction bearings in good condition (before turning, remove possible bearing locking device).
2. Check the bearing locking periodically (horizontal machines with cylindrical roller bearing and vertical machines may be provided with a locking device to protect the bearings against damage during transport and storage). Tighten the shaft end locking screw to the required degree depending on the axially locating bearing type (Tables 1 and 2). A too tight fixing can damage the bearing.

Table 1. Tightening torque for horizontal machines (lubricated screw). Axially locating bearing = deep groove ball bearing carries the locking force.

Axially locating bearing type	Tightening torque [Nm]
6317	50
6319	60
6322	120
6324	140
6326	160
6330	240
6334	300
6034	140

Table 2. Tightening torque for vertical machines (lubricated screw). Axially locating bearing = angular contact ball bearing carries the locking force.

Axially locating bearing type	Tightening torque [Nm]
7317	30
7319	30
7322	60
7324	60
7326	90
7330	160
7334	350

4.3.2 Sleeve bearings

Apply also the following measures:

1. If the storing period is longer than two months, spray Tectyl 511 or other anti-corrosion film-forming oil to the bearing through the filling hole.
2. Dismount the upper cover of bearing housing every six months. Check the anti-corrosion oil layer of the shaft and the inside of the bearing. Repeat the anti-corrosion protection.
3. If the storing period is longer than two years, the bearing has to be taken apart and treated separately. If the environment is humid, a package of Silica-Gel can be placed in the bearing case.
4. After storage it is recommended that the bearings are opened according to the dismantling notes, and the bearing journal and lining are inspected before

commissioning. Remove any corrosion with a fine emery cloth. If the shaft has left imprints on the lower liner-half, replace it with a new one.

5. Check the bearing locking periodically (machines with sleeve bearings are provided with a locking device to protect the bearings against damage during transport and storage). Tighten the shaft end locking screw to the required degree depending on the axially locating bearing type (Table 3). A too tight fixing can damage the bearing.

Table 3. Tightening torque (lubricated screw). Axially locating bearing carries the locking force.

Axially locating bearing type	Tightening torque [Nm]
RENK ZMNLB 7	100
RENK EFZLB 9	250
RENK EFZLB 11	300
RENK EFZLB 14	600

4.4 Inspections, records

The conservation period, used methods and measures with dates should be recorded.

4.5 Care after installation

If the machine is not in operation for a long time after installation, the measures described earlier apply. If external vibration is present, the shaft coupling should be opened and suitable rubber blocks should be placed under the feet of the machine.

Chapter 3 – Installation and Alignment

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1 General

Calculation and design of the foundation is not included in the ABB undertaking and the customer or the third party is therefore responsible for it. Furthermore, the grouting operation is also normally outside ABB undertaking and responsibility.

When a machine is purchased, available lifting capacity, lifting height, roads for transport, spare parts, installation tools etc. should be checked.

2 Design of foundation

The foundation design should assure safe running conditions with maximum accessibility. Sufficient free space should be left around the machine to ensure easy access for maintenance and monitoring. The cooling air should flow to and away from the machine without obstruction.

Care has to be taken that other machines or equipment near do not heat the machine's cooling air. The incoming cooling air of the machine must have the same temperature as surrounding air.

The foundation must be strong and rigid. It shall be flat and free from external vibration. To avoid resonance vibrations with the machine it shall be designed so that the natural frequency of foundation together with machine is not within ±20% range of running speed frequency.

Concrete foundation is preferred, however, a correctly designed steel construction is also acceptable. Anchorage to the foundation, provision of air, water, oil and cable channels as well as location of grouting holes should be considered prior to construction.

The foundation and the mounting bolts must be dimensioned to withstand a sudden mechanical torque, which occurs when starting the machine or at short circuit. The short circuit force is a gradually damped sine wave type vibration that changes direction. The machine has to be tightly bolted to the foundation, in order for the machine to be as vibration free as possible.

2.1 Horizontal foot mounted machines

The stress imposed on the foundation for horizontal foot mounted machine can be calculated with the aid of the following formulas and Figure 1:

SI: $F = 0.5 \times g \times m \pm \frac{8 \times T}{A}$ where

F	=	stress on foundation per side	[N]
g	=	acceleration due to gravity	[m/s2]
m	=	weight of the machine	[kg]
T	=	rated torque of the machine	[Nm]
A	=	distance between mounting holes	[m]

US: $F = 0.5 \times W \pm \frac{8 \times T}{2E}$ where

F	=	stress on foundation per side	[lbf]
W	=	weight of the machine	[lbf]
T	=	rated torque of the machine	[lbf x ft]
2E	=	distance between mounting holes	[ft]

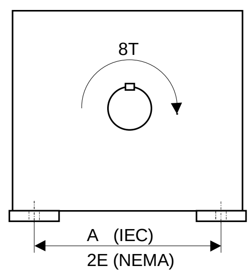


Fig. 1. Dimensions A and 2E.

The foundation shall be designed to permit 2 mm (0.8 inch) shim plates under the feet of the machine. That is to ensure an adjusting margin and facilitate the installation of a replacement machine with different shaft height compared to the original machine.

Position of the grouting holes and height of the foundation must agree with corresponding dimensions on the provided dimensional drawing.

2.2 Vertical flange mounted machines

Vertical flange mounted machines are equipped with a mounting flange. The flange of the machine will always be mounted to the opposite flange on foundation.

A mounting adapter is recommended to enable an easy coupling connection and inspection during operation.

3 Installation of horizontal foot mounted machines

3.1 Scope of delivery

As a standard the machine delivery does not include shim plates, mounting bolts, foundation plate set or sole plate set. These are delivered according to special order. The following Paragraphs include the installation procedure of foundation or sole plate set onto a concrete foundation. If a rigid steel foundation is used, proceed straight to Paragraph “Alignment”.

3.2 General preparations

Before starting of the installation procedure, take the following aspects into account.

- Reserve 2 mm (0.8 inch) shim plates to be used between the machine feet and the foundation.
- Reserve sheet steel material for shimming under the feet of the machine. Possible adjustments require shim thickness of 1, 0.5, 0.2, 0.1 and 0.05 mm (40, 20, 8, 4 and 2 mil).
- Reserve adjusting screws or hydraulic jacks for axial and horizontal adjustment.
- Reserve dial indicator gauges or preferably a laser optical analyzer to achieve accurate and precise alignment within the specified tolerances.
- Provide sun and rain protection to eliminate measuring errors during installation.

3.3 Machine preparations

Prepare the machine for installation as follows:

- Remove the bearing locking device. Store it for future transportation and storage.
- Fill appropriate oil through the filling holes into the sleeve bearings. A simple lever arm is needed for turning the rotor during alignment.
- Remove the anti-corrosive coating on shaft end and machine feet with white spirit. Install the coupling half as described in Chapter “Mechanical and Electrical Connections”.
- Check that the drain plugs at the lowest part of both ends of the machine are in open position (half of the plug inside and half outside).

3.4 Foundation and grouting hole preparations

To prepare the foundation take the following aspects into account:

- The upper part of the foundation has to be swept or vacuum cleaned.
- Walls of the grouting holes must have rough surfaces to give a good grip. For the same reason they must be washed and rinsed. Oil or grease must be removed by chipping away slices of the concrete surfaces.
- A steel wire is attached on the foundation to indicate the center line of the machine. The axial position of the machine should also be marked.

3.5 Foundation plate or sole plate preparations

To assemble the foundation plate or sole plate set, the machine must be suspended above the floor. Proceed as follows (Appendix 1):

1. Screw greased leveling screw (6) to the foundation plates (1) or sole plates (1).
2. Wrap a layer of tape (not in the foundation plate or sole plate delivery) around the upper part of the anchor bolts (2) according to Appendix 1. The tape prevents this part of the bolt from getting stuck in the concrete and enables it to be retightened after the concrete has set.
3. Fit the anchor bolt (2) in the foundation plates (1) or sole plates (1) so that the top of the anchor bolts is 1...2 mm (40...80 mil) above the upper surface of the nuts (4).
4. Fit the anchor flange (3) and the lower nut (4) to the anchor bolts (2). Bridge the anchor flange (3) to the bolts by welding and tighten the nuts. If the bridging cannot be done, lock the anchor flange between two nuts.
5. Mount the foundation plate (1) or sole plate (1) under the machine foot with the mounting bolt (8) and washer (9). Before that, clean the anti-corrosive coating on the upper surface of the foundation plate or sole plate with white

spirit. Center the mounting bolt (8) in the hole of the machine by wrapping e.g. paper, cardboard or tape around the upper part of the bolt.

6. Place the 2 mm (0.8 inch) shim (7) between the foot and the plate (1). Fasten the plate tightly against the foot with a mounting bolt (8).
7. Place the leveling plate (5) under the levelling screw (6) and a thin sliding plate (not in the foundation plate or sole plate delivery) under the levelling plate. The sliding plate is made of steel and it helps to move the machine sideways and in axial direction.
8. Check that the space between the plate (1) and the anchor bolts (2) is tight. If concrete penetrates through this interstice up to the nuts, the retightening cannot be done.

When the assembly is done and the machine is still suspended above the floor, machine feet, sides and bottom surfaces of the plates as well as anchor bolts are cleaned with white spirit. To ensure that the anchor bolts and plates are satisfactorily attached to the concrete, they must be unpainted.

After the previous steps the machine is ready to be erected onto the foundation.

3.6 Erection onto the foundation

The machine is lifted and placed onto the foundation. A rough horizontal alignment is made with the aid of the previously installed steel wire and the marking of the axial location. A vertical alignment is made with the levelling screws. Required positioning accuracy is within 2 mm (80 mil).

3.7 Grouting

Grouting of the machine into the foundation is a very important part of the installation. Problems can arise if materials are of poor quality, which may show up early or after several months of operation.

After the settings and alignment checks, the anchor bolts are grouted into the concrete. The instructions of the grouting compound supplier must be followed. Cracks in the grouting compound or a poor attachment to the concrete foundation cannot be accepted.

3.8 Final installation

Retighten the anchor bolt nuts after the concrete has set. Lock the nuts by bridging or hitting sufficiently hard with a center punch.

4 Installation of vertical flange mounted machines

4.1 General preparations

Before starting of the installation procedure, take the following aspects into account.

- Reserve a recoil hammer and other equipment for horizontal adjustment.
- Reserve dial indicator gauges or preferably a laser optical analyzer to achieve accurate and precise alignment within the specified tolerances.
- Provide sun and rain protection to eliminate measuring errors during installation.
- Clean the mounting flange of the foundation.

4.2 Machine preparations

Prepare the machine for installation as follows:

- Remove the bearing locking device. Store it for future use.
- Remove the anti-corrosive coating on shaft end and machine flange with white spirit. Install the coupling half as described in Chapter “Mechanical and Electrical Connections”.
- Check that the two drain plugs at the lower end shield of the machine are in open position (half of the plug inside and half outside).

After the previous steps the machine is ready to be erected onto the mounting flange of the foundation.

4.3 Erection onto the mounting flange

The machine is lifted and placed onto the mounting flange. The mounting bolts are tightened lightly.

5 Alignment of horizontal foot mounted machines

5.1 General

When a machine is aligned with another machine, the radial as well as the angular deviation between the two shafts have to be minimized.

Before the alignment procedure is started, the coupling halves have to be installed. Refer to the Chapter “Mechanical and Electrical Connections” for installation of the coupling half of the machine. In order to move freely during alignment, the coupling halves must be bolted together loosely.

5.2 Rough levelling

To facilitate the alignment in the vertical plane and enable the mounting of earlier mentioned shim plates, jacking screws are fitted to the feet of the machine (Figure 2). Do not ever tight the mounting bolts against jacking screws, use always shim plates. The level is checked for example with a spirit level. The machine must stand on all four feet (feet shall be plain parallel within 0.1 mm (4.0 mil) or better).

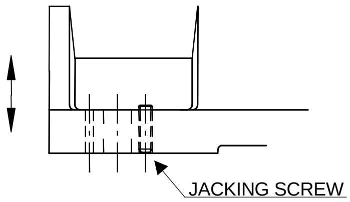


Fig. 2. Vertical positioning.

5.3 Rough adjusting

To facilitate the alignment in offset and axial directions, place the bracket plates with adjusting screws at corners (Figure 3).

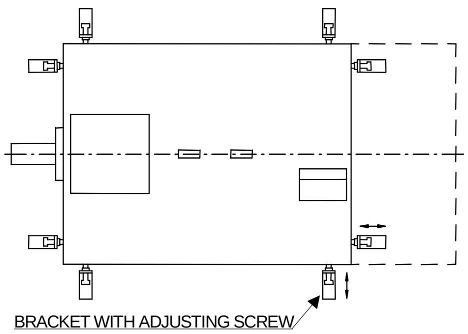


Fig. 3. Positioning of bracket plates.

Bracket plates are placed against the foundation edge and tied down with an expansion bolt (Figure 4).

Move the machine by using the four axial adjusting screws until the shaft centerline and the driven machine centerline are aligned roughly and the desired distance between the coupling halves is reached. Leave all adjusting screws only lightly tightened.

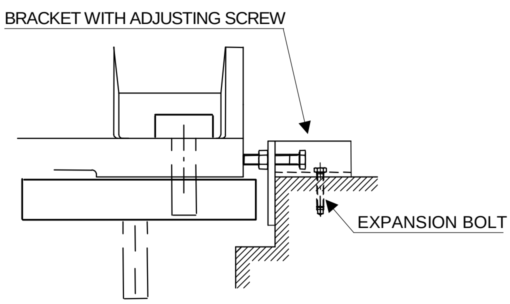


Fig. 4. Mounting of the bracket plate.

5.4 Correction for thermal growth

Temperatures have a considerable influence and should therefore be considered during the alignment. The machine temperature is lower during erection than under operating conditions. Therefore it may be necessary to use compensating alignment. This depends on the operating temperature of the driven machine, coupling type, distance between machines, etc.

5.4.1 Growth upwards

The thermal growth of the electrical machine upwards can be approximately calculated according to the formula:

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

ΔH = thermal growth [mm]
α = $10 \times 10^{-6}\ K^{-1}$
ΔT = 30 K (AM_ machines), 40 K (HXR machines)
H = shaft height [mm]

5.4.2 Axial growth

The expected thermal growth of the rotor in proportion to the stator frame, in case of fixed bearing in the N-end, can be approximately calculated according to the formula:

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

ΔL = thermal growth [mm]
α = $12 \times 10^{-6}\ K^{-1}$
ΔT = 50 K (AM_ machines), 100 K (HXR machines)
L = frame length [mm]

5.5 Alignment check

In the following Paragraphs and Checklist 3 in Chapter "Checklists" the alignment check is done with dial gauges, although there are more exact, modern and common used measuring equipment in the market (e.g. laser optical systems). The reason for that is to give a background of the alignment theory.

The alignment check results should always be recorded in a log.

5.5.1 Run-out at the coupling halves

Alignment check is started by measuring the run-out at the coupling halves. This measurement will show possible inaccuracy of the shaft / coupling half systems.

Measure the run-out at the coupling half of the machine in respect to the bearing housing of the machine (Figure 5). Respectively, check the run-out at the coupling half of the driven machine in respect to the bearing housing of the driven machine. A simple lever arm is needed to turn a rotor of a sleeve bearing machine (fill the bearing with oil before turning). Admissible run-out error is ≤ 0.02 mm (0.8 mil).

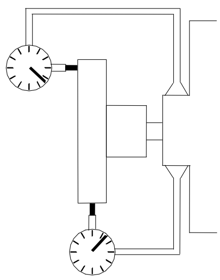


Fig. 5. Measuring the run-out at the coupling half.

5.5.2 Radial and axial misalignment

If the run-out measurements verify that the shaft/coupling systems are in acceptable condition, mount the gauge to the coupling flanges by means of suitable fastening devices (eliminate the possibility of sag). The following measurement will show possible alignment or installation inaccuracies.

All readings for radial and axial misalignment are determined in the gauge positions: top, bottom right and left, i.e. every 90°, while both shafts are simultaneously turned (Figure 6). Finally check the axial distance between the two coupling halves.

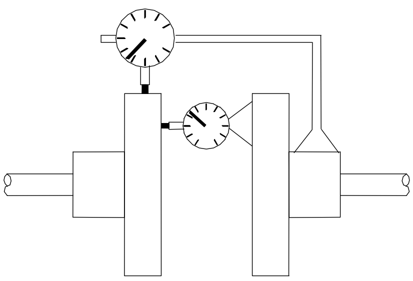


Fig. 6. Measuring the radial and axial misalignment and distance between the two coupling halves.

Correct the possible misalignment by adding or removing shim plates or turning the adjusting screws until the acceptable tolerances are reached. Refer to the values presented in Paragraph 7, “Acceptable misalignment”.

After the acceptable tolerances are reached, the mounting bolts are tightened to the required degree (M20 334 Nm, M24 569 Nm, M27 839 Nm, M30 1138 Nm, M36 1991 Nm, M39 2570 Nm, M42 3178 Nm, M48 4601 Nm). Coupling halves are disconnected to wait for a test run according to Chapter“ Commissioning and Start-up”.

After the test run is made and machine/driven machine system has been running within the permissible vibration until normal operating temperatures are reached, the machine is stopped and alignment is checked. If corrections are needed, proceed them as presented earlier.

Now the machine is ready for doweling the feet of the machine and completing the installation and alignment procedure.

5.6 Doweling of the machine feet

The machine has one dowel hole per foot of the machine at the D-end. Deepen the holes by drilling to the steel foundation. After that the holes are tapered with a scraper tool. Suitable tapered pins are fitted to the holes to ensure the exact alignment and easier the possible new installations.

6 Alignment of vertical flange mounted machines

6.1 General

When a machine is aligned with another machine, the radial as well as the angular deviation between the two shafts have to be minimized.

Before the alignment procedure is started, the coupling halves have to be installed. Refer to the Chapter “Mechanical and Electrical Connections” for installation of the coupling half of the machine. In order to move freely during alignment, the coupling halves must be bolted together loosely.

When the mating surfaces of the flanges on machine and on foundation are compatible, the alignment is easier to perform than the alignment of a foot mounted machine.

6.2 Axial thermal growth and coupling type

Temperatures have a considerable influence and should therefore be considered during the alignment. The machine temperature is lower during erection than under operating conditions. Therefore it may be necessary to use compensating alignment. This depends on the operating temperature of the driven machine, coupling type, distance between machines, etc.

6.3 Alignment check

In the following Paragraphs and Checklist 3 in Chapter "Checklists" the alignment check is done with dial gauges, although there are more exact, modern and common used measuring equipment in the market (e.g. laser optical systems). The reason for that is to give a background of the alignment theory.

The alignment check results should always be recorded in a log.

6.3.1 Run-out at the coupling halves

Alignment check is started by measuring the run-out at the coupling halves. This measurement will show possible inaccuracy of the shaft/ coupling half systems.

Measure the run-out at the coupling halve of the machine in respect to the bearing housing of the machine (Figure 7). Respectively, check the run-out at the coupling halve of the driven machine in respect to the bearing housing of the driven machine. Admissible run-out error is ≤ 0.02 mm (0.8 mil).

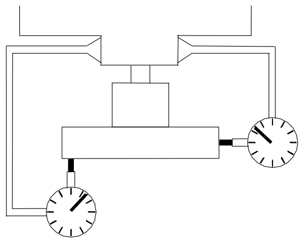


Fig. 7. Measuring the run-out at the coupling flange.

6.3.2 Radial and axial misalignment

If the run-out measurements verify that the shaft/ coupling systems are in acceptable condition, mount the gauge to the coupling flanges by means of suitable fastening devices (eliminate the possibility of sag). The following measurement will show possible alignment or installation inaccuracies.

All readings for radial and axial misalignment are determined in the gauge positions: top, bottom right and left, i.e. every 90°, while both shafts are simultaneously turned (Figure 8). Finally check the axial distance between the two coupling halves.

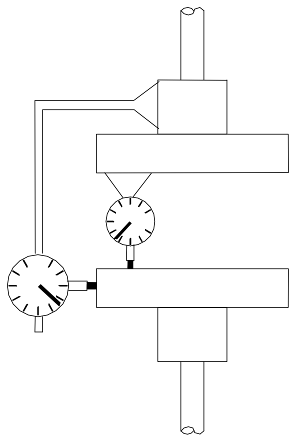


Fig. 8. Measuring the radial and axial misalignment and distance between the two coupling halves.

Correct the possible misalignment with a recoil hammer by hitting the shield of the machine lightly to the needed direction until the acceptable tolerances are reached. Refer to the values presented in Paragraph 7, "Acceptable misalignment".

After the acceptable tolerances are reached, the mounting bolts are tightened to the required degree (M20 334 Nm, M24 569 Nm, M27 839 Nm, M30 1138 Nm, M36 1991 Nm, M39 2570 Nm, M42 3178 Nm, M48 4601 Nm). Coupling halves are disconnected to wait for a test run according to Chapter" Commissioning and Start-up".

After the test run is made and machine/driven machine system has been running within the permissible vibration until normal operating temperatures are reached, the machine is stopped and alignment is checked. If corrections are needed, proceed them as presented earlier.

7 Acceptable misalignment

Maximum permissible radial misalignment and axial displacement (Figure 9):

Δr, Δa

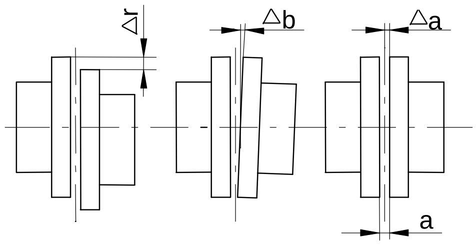
Rigid flange coupling	Δr, Δa ≤ 0.02 mm (0.8 mil)
Gear coupling	Δr, Δa ≤ 0.05 mm (2 mil)
Flexible coupling	Δr, Δa ≤ 0.10 mm (4 mil)

Δb (coupling flange diameter 100...250 mm)

Rigid flange coupling	Δb ≤ 0.01 mm (0.4 mil)
Gear coupling	Δb ≤ 0.03 mm (1 mil)
Flexible coupling	Δb ≤ 0.05 mm (2 mil)

Δb (coupling flange diameter 250...500 mm)

Rigid flange coupling	Δb ≤ 0.02 mm (0.8 mil)
Gear coupling	Δb ≤ 0.05 mm (2 mil)
Flexible coupling	Δb ≤ 0.10 mm (4 mil)



Radial misalignment Δr
Gap (angular displacement) Δb
Axial displacement Δa

Fig. 9. Measuring the run-out at the coupling.

The normal accepted misalignments are as above. A definite tolerance is impossible to state because too many factors have an influence.

Because the tolerances given by the coupling manufacturers indicate what the coupling can survive, do not use them for judgement of how accurate the alignment should be. Too large tolerances will cause vibration and lead to bearing/machine damage. Therefore it is recommended to aim at as narrow tolerances as recommended.

The alignment of the machine must be performed with great caution. Remember to log all measurements, used devices and methods for future checks.

8 Belt drive

Machines designed for belt drives are always equipped with cylindrical roller bearing in the D-end.

Note! Do not exceed the radial force specified in the order definitions.

If a belt drive is used, make sure that the driving and the driven pulleys are correctly aligned.

Note! Suitability of the shaft-end and the bearings for the belt drive must be checked allways before use.

Note! IC611 AMK-machines are normally not suitable for belt drive operation.

Chapter 4 - Mechanical and Electrical Connections

Chapter 4 - Mechanical and Electrical Connections

1 General

Mechanical and electrical connections are made after installation and alignment procedure. Mechanical connections include connection of coupling halve, air ducts, water tubes or oil supply system as applicable. Electrical connections include connection of main and auxiliary cables, earthing cables and possible external blower motor. Follow the next Paragraphs and Checklist 4 in Chapter "Checklists" as applicable.

> **Note!** Additional installation holes or threads should never be drilled trough the frame.

2 Mechanical connections

2.1 Assembly of the coupling half

2.1.1 Balancing

As a standard the rotor is dynamically balanced with half key. The way of balancing is stamped to the shaft end as H = half key and F = full key. The coupling half must be balanced respectively.

2.1.2 Assembly

When assembling the coupling half, take the following instructions into account:

- Clean the shaft extension from anti-corrosive coating and check measurements of extension and coupling against the provided drawings. Ensure also that the keyways in the coupling and the shaft extension are clean, free from burrs and truly parallel.
- Coat the shaft extension and hub bore with a thin layer of cylinder oil. Never coat mating surfaces with molybdenum diosulphide (Molykote) or similar products.
- The weight of the coupling half can be considerable. Suitable lifting gear may be needed.
- The coupling must be covered with a touch guard.
- Follow the coupling supplier´s instructions.

> **Note!** No additional forces should be caused to the bearings during the coupling half assembly.

2.2 Coupling type

2.2.1 Machines with antifriction bearings

When the machine is equipped with antifriction bearings, it must be connected to the driven machine with flexible coupling (pin couplings, gear couplings).

Make sure that continuous free axial movement is possible between the coupling halves in order to permit thermal expansion of the machine shaft without damaging the bearings. The expected axial thermal growth of the rotor can be calculated as defined in Chapter "Installation and Alignment".

Vertical machine may be designed to carry some load from the shaft of the driven machine. Then the coupling halves have to be locked against slipping in the axial direction e.g. by a lock plate on the end of the shaft.

2.2.2 Machines with sleeve bearings

Sleeve bearing construction allows the rotor to move axially between mechanical end float limits. Standard bearings can not withstand any axial force from the driven machine. Therefore all axial force must be carried by the driven machine and coupling must be of limited axial float type.

Sleeve bearing is equipped with a pointer for running center which is marked with a groove on the shaft. There are also grooves on the shaft for rotor mechanical end float limits. The pointer must always be within the limits (Figure 1). Notice that the running center is not necessarily the same as the magnetic center (fan may pull the rotor from the magnetic center).

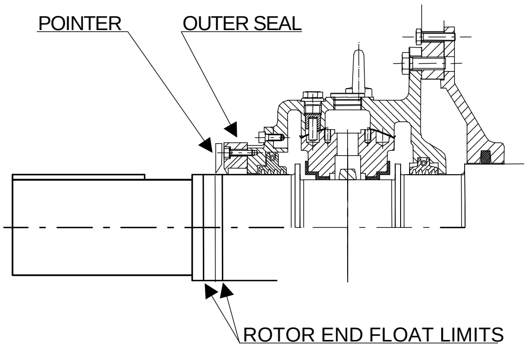


Fig. 1. Markings on shaft and running center pointer.

2.3 Air connections

Machines designed for cooling air flow to and / or from the machine with ducts have connection flanges specified in the dimensional drawing. Connect the ducts and seal the joints with appropriate gaskets. After connection, perform a check for possible leaks and obstructions.

2.4 Water connections

Machines equipped with an air-to-water heat exchanger have flanges specified in standards DIN 633 or ANSI B 16.5. Connect the flanges and seal the joint with appropriate gasket. After connection, perform a check for possible leaks.

2.5 Oil supply system

Sleeve bearing machines may be designed to have a forced lubrication system. In that case the bearings are equipped with flanges to connect all necessary oil pipes. Running of the machine without connection to the oil supply system prevents the bearings to have an appropriate lubrication. That results immediately in a bearing damage.

Start the connection by cleaning all oil pipes and rinsing them with rinsing oil. A pressure gauge and a flow indicator are often provided at the oil inlet. These are normally already fitted before delivery.

Install the outlet pipes downwards from the bearings at a minimum angle of 10° which corresponds to 160 to 170 mm/m (2 - 2½ in/ft). The oil level will increase if the oil is flowing too slowly from the bearing sump. This can result in oil leaks or disturbances in the flow.

Install the oil supply system near the machine in equal distance from each bearing. Test the oil supply system first by using rinsing oil. After this, remove the oil filter and clean it. Then connect the pipes and fill the oil supply system and bearings with appropriate oil. After connection, perform a check for possible leaks. Prior to starting the machine, oil supply has to be turned on.

3 Electrical connections

3.1 Safety

Electrical connections must be carried out only by skilled persons on the machine at rest. The following safety rules must be strictly applied:

- De-energize!
- Provide safeguard against reclosing!
- Verify safe isolation from supply!
- Connect to earth and short!
- Cover or provide barriers against neighbouring live parts!
- De-energize auxiliary circuits (e.g. anti-condensation heating)!

Exceeding of limit values of zone A in EN 60034-1 / DIN VDE 0530-1 - voltage ± 5%, frequency ± 2%, waveform and symmetry - leads to higher temperature rise and affects the electromagnetic compatibility. Note rating plate markings and connection diagram in the terminal box.

The clearances between uninsulated live parts and between such parts and earth must not be below the following values: 8 mm at UN ≤ 550 V, 10 mm at UN ≤ 725 V, 36 mm at UN ≤ 3.3 kV, 60 mm at UN ≤ 6.6 kV and 100 mm at UN ≤ 11 kV.

Connection must be made in such a way that permanent safe electrical connection is maintained. Appropriate cable terminals must be used. The proper installation (segregation of signal and power lines, earthing, screened cables etc.) lies within the installer's responsibility.

3.2 EMC requirements for machines fed with frequency converter

Compliance with the EMC directive (89/336/ EEC, as amended by 93/68/EEC) requires that the AC machine fed with frequency converter is installed with screened cables specified below. For information on other equivalent cables, please contact your local ABB representative.

3.2.1 Main cable

The main cable installed between the machine and the frequency converter must be a symmetrical three conductor screened cable in order to fulfil the radiated emission requirements stated in the generic emission standard for industrial environment EN 50081-2. The cable types MCCMK and AMCCMK from NOKIA KAAPELI and VUSO and VO-YMvK-as from DRAKA KABEL have been tested and approved by ABB for low voltage (<1 kV) frequency converter applications. Equivalent cables from other manufacturers can be used as well.

3.2.2 Earthing of main cable

EMC directive requires high frequency earthing of the main cable. This is achieved by a 360° earthing of the cable screens at the cable entries both in the machine and in the converter. The earthing at the machine is implemented for example by means of the EMC ROX SYSTEM cable transits for shielded installations.

Note! 360° high frequency earthing of cable entries is done in order to suppress electromagnetic disturbances. In addition, cable screens have to be connected to protective earth (PE) in order to meet safety regulations.

3.2.3 Auxiliary cables

The auxiliary cables must as well be screened to meet the EMC requirements. Special cable glands must be used for the 360° high frequency earthing of the cable screens at the cable entries.

3.3 Main terminal box and connection of main cables

The inside of main terminal box must be free of dirt, moisture and foreign bodies. The box itself, cable glands and unused cable entrance holes must be closed in a dust- and watertight manner.

The main terminal box is equipped with a drain plug at the lowest part of the end plate. The plug should be in open position (half of the plug inside and half outside) during transportation and storage. During operation the plug should be kept in shut position but opened from time to time. If the box is turned after delivery the drain plug functioning must be checked and positioned at lowest part of the box.

Before the connection of cables can be started, the connection diagrams delivered with the machine have to be studied carefully. It is important to verify that the supply voltage and the frequency are the same as the values indicated on the rating plate of the machine.

The size of input cables have to be adequate for the maximum load current and in accordance with local standards. The cable terminals have to be of appropriate type and of correct size.

Note! Prior to connection work, it is important to check that the incoming cables are separated and earthed properly.

The stator terminals are marked with letters U, V and W according to IEC 34-8 or with T1, T2 and T3 according to NEMA MG-1. A neutral terminal is marked with N (IEC) or with T0 (NEMA). When the supply cables are connected U, V and W and the phase sequence is L1, L2 and L3, the machine will rotate in clockwise direction (looking at the D-end).

Figure 2 presents standard medium voltage terminal boxes according to IEC and NEMA standards.

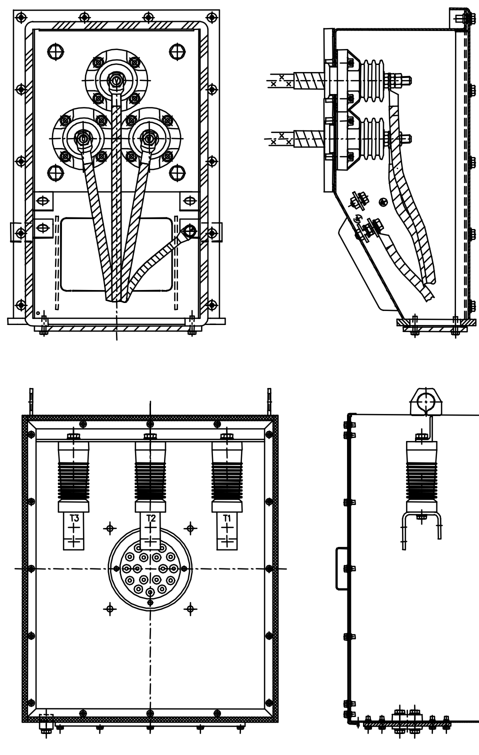


Fig. 2. Main terminal boxes: IEC medium voltage (upper) and NEMA medium voltage.

Main terminal boxes can be turned in 90 degrees steps. Before turning, check that the length of the cables is sufficient.

Main cable phases with lugs are tightened to stator terminals with connecting nuts. Tightening torque presented in Table 1 should be applied.

Table 1. Tightening torque of the connecting nut.

The size and material of the connecting nut	Tightening torque [Nm]
M12 (Steel)	75…83
M16 (Bronze)	40

3.4 Connection of secondary cables (AMK machines only)

The slip ring housing serves as a terminal box for the secondary cables. It has the same degree of protection as that of the machine. The cables can be connected from either the right or left hand side.

The cable entry flange is according to DIN 42962 and up to four 100 mm diameter cables can be connected per side. The connection is made to rotor terminals on the termination plate, that is designed to fit up to 6 cable lugs / phase. The terminals are marked K, L and M in accordance with IEC Publications 34-8.

Before the connection of cables can be started, the connection diagrams delivered with the machine have to be studied carefully.

3.5 Auxiliary terminal box and connection of accessories

Auxiliary terminal box(es) are attached to the frame of the machine according to accessories and customer needs.

Auxiliary terminal boxes are equipped with terminal blocks and cable glands (Figure 3). The maximum size and voltage of the cables is limited to 2,5 mm^2 and 750 V. Cable glands are in accordance with DIN 46320 Teil 1.

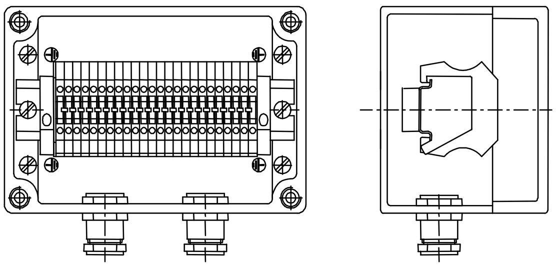


Fig 3. Auxiliary terminal box.

Before the connection of accessories can be started, the connection diagrams delivered with the machine have to be studied carefully. The connection and functioning of accessories must be checked before commissioning.

Terminals of accessories, which are normally under voltage when the machine is switched off (e.g. space heaters), must be correspondingly labelled.

Note! Circuit may be live!

3.6 Earth connections

The machine frame, main terminal box and associated equipment must be connected to the earth with suitable cable blocks. Earth connection and the power supply have to be such that harmful or dangerous potential can not be created to the machine frame. Voltage under 250 mV between the shaft and the frame does typically not cause any harm to the product e.g. bearings. Mark the machine and terminal boxes with earth symbol according to relevant national standards.

Note! Warranty is not valid if bearing is destroyed due to wrong earthing or cabling.

3.7 Connection of external blower motor

The external blower motor is normally three phase asynchronous motor. The motor rating plate shows the voltage and frequency. The direction of rotation is indicated by an arrow plate on the flange of the machine.

Note! Check the direction of rotation of the external blower motor before starting the machine.

If the motor is running in wrong direction, the phase sequence must be changed.

Chapter 5 – Commissioning and Start-up

Chapter 5 – Commissioning and Start-up

1 Insulation resistance

1.1 General

Before a machine is started up for the first time, after a long period of standstill or within the scope of general maintenance work, the winding insulation resistance shall be measured. For squirrel cage machines this includes the measuring of the stator winding. For slip ring machines the measuring includes also the rotor winding.

The insulation resistance measurements provide information about the humidity and dirtiness of the insulation. Consequently, necessary measures for cleaning and drying can be determined. New machines and machines with new windings have normally very high resistance insulation. However, unsuitable transportation or storage conditions might subject the machine to such extremely moist conditions that the insulation resistance becomes far too low.

1.2 Criteria for human safety

For safe (human safe) starting of the machine, minimum acceptable insulation resistance of the windings at temperature 40°C (104°F) can be determined by using the following formula:

$R_{40°C} = 1 + U_N$

where:

$R_{40°C}$ = insulation resistance [megaohms, MΩ]
U_N = rated supply voltage of the machine [kV]

1.3 Criteria for dry winding

To judge if a winding has got moist, higher insulation resistance limits than those defining the safe starting conditions (human safety) must be considered. For a clean and dry winding the insulation resistance value is typically very high - in the order of thousands of megaohms. Depending on the winding type, the insulation resistance value may be very sensitive to moisture inside the machine. As a thumb rule 1000 MΩ is recommended to be applied as the minimum accepted insulation resistance value prior starting a machine.

In general, if a machine is suspected to have got moist it shall be dried carefully independent on the measured insulation resistance value.

The insulation resistance value will decrease when the winding temperature rises. The resistance is halved for every 10...15 K temperature rise.

1.4 Measuring the insulation resistance of stator winding

The insulation resistance of the stator winding is measured with an insulation resistance indicator. Required notes and measures:

- All power supply cables are disconnected.
- The frame of the machine and the stator winding phases not been tested are earthed.
- All resistance temperature detectors (RTD) are earthed.
- Measurement device is checked.
- Winding temperatures are measured.
- Measured insulation resistance values are compared with values given in the test report.

Usually the star point connection or delta connection of high voltage machine can not be opened. Then the indicator should be connected between the whole winding and the frame of the machine, the frame earthed. (Figure 1).

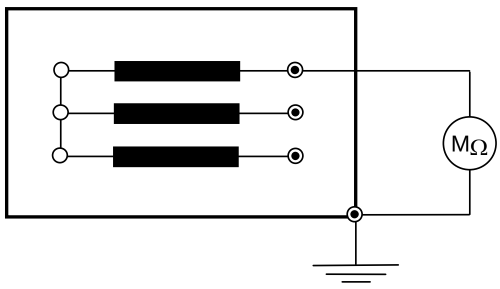


Fig. 1. Measuring the insulation resistance of the whole stator winding.

If it is possible to open the star point connection, the indicator should be connected between one winding phase and the frame of the machine at a time, all other phases and the frame earthed (Figure 2).

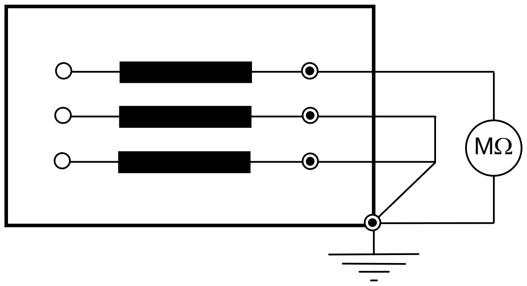


Fig. 2. Measuring the insulation resistance of an individual stator winding phase.

Note! After measurement the winding phases must be earthed for discharging them.

1.5 Measuring the insulation resistance of rotor winding (AMK machines only)

The insulation resistance of the rotor winding is measured with an insulation resistance indicator. Required notes and measures:

- All power supply cables are disconnected.
- The slip ring unit connection cables are disconnected.
- The frame of the machine and the stator winding are earthed.
- The shaft and rotor winding phases not been tested are earthed.
- The carbon brush connections are checked.
- Measurement device is checked.
- Stator winding temperatures are measured (considered as a reference value for the rotor winding temperature).
- Measured insulation resistance values are compared with values given in the test report.

The indicator is connected between one winding phase and the shaft of the machine at a time, all other phases and the shaft earthed (Figure 3).

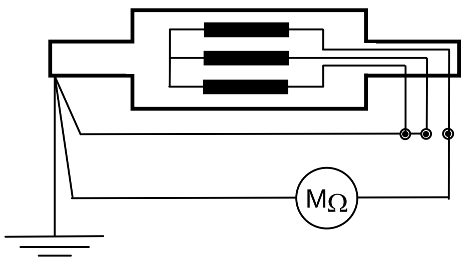


Fig. 3. Measuring the insulation resistance of an individual rotor winding phase.

Note! After measurement the winding phases must be earthed for discharging them.

1.6 Measuring value

The insulation resistance of new machine is normally very high. As a thumb rule it can be taken that if the measured value is one decade or more lower than the value measured in the factory, check the winding for excess moisture or dirt, as well as the calibration of the measuring device. The test report contains the insulation resistance value measured in the factory.

2 Drying the windings

If the windings have been affected by damp to an extent that the insulation resistance is too low, dry the windings. For drying the windings see Chapter "Maintenance".

3 Protections

The machine has to be protected against various disturbances that might damage it. Protections must be in accordance with the instructions and regulations for each country.

Protective relays are used to protect the equipment from different disturbances and stresses, e.g. overloading in operation, or in starting (like too long or too many consecutive or stall startings), supply disturbances or faults, switching errors and insulation faults like earth faults. The scope of relay protection in practice depends on the actual application characteristics, local network and other protective means, which may be needed.

The machine parameter values for relay settings are informed in the document “Performance data of machine”, which is delivered after order.

Note! ABB is not responsible for relay settings at site.

4 Alarm and trip limits of the control equipment

4.1 Stator winding temperature control

4.1.1 Resistance temperature detectors (RTD)

With Pt-100 and other corresponding elements, alarm and trip limit temperatures should be set as low as possible based on the test results and empirical operating temperature behaviour of the machine. Alarm limit can be set e.g. 10 and trip limit 20 K higher than the winding temperature of the machine at max load at highest ambient temperature.

Recommended settings:

1 function:	trip	120-140°C (250-285°F)
2 functions:	alarm	120-140°C (250-285°F)
	trip	130-150°C (265-300°F)

The maximum recommended settings defined to protect the windings are:

1 function:	trip	160°C (320°F)
2 functions:	alarm	160°C (320°F)
	trip	180°C (355°F)

4.1.2 Thermistors (PTC)

If the machine is equipped with three thermistors, the operating temperature of the thermistors is 150°C (300°F). The operating function can be chosen to be alarm or trip signal. If the machine is equipped with six thermistors, the operating temperatures are 150°C (300°F) and 170°C (340°F). In that case both alarm and trip signals can be used.

4.2 Bearing temperature control

4.2.1 Resistance temperature detectors (RTD)

With Pt-100 and other corresponding elements, alarm and trip limit temperatures should be set as low as possible based on the test results and empirical operating temperature behaviour of the bearings. The maximum recommended settings for normal operating with standard lubricants are:

Antifriction bearings

1 function:	trip	90°C (195°F)
2 functions:	alarm	85°C (185°F)
	trip	90°C (195°F)

The limits can be set 20°C (70°F) higher, when appropriate high temperature grease is used. See Chapter “Maintenance”.

Sleeve bearings

1 function:	trip	90°C (195°F)
2 functions:	alarm	85°C (185°F)
	trip	90°C (195°F)

The limits can be set 10°C (50°F) higher, when appropriate high temperature oil is used. See Chapter “Maintenance”.

4.3 Tripping

In case of tripping, the reason must always be found out and eliminated before the machine is restarted. Use Trouble-Shooting 1 and 2 for finding out the reason.

5 Test start

Test start is a standard procedure after the installation and alignment procedure is finished, mechanical and electrical connections (except the coupling connection) are made, commissioning procedure is gone through and protective devices are active. See Checklist 5 in Chapter “Checklists”.

5.1 Starting of AMK machines

Slip ring machine type AMK can not be started without a starter. Starter is typically a variable resistance connected to each rotor phase. Selection of starter is done according to required starting torque and current. Typically starting is done with nominal current and nominal torque.

During starting the starter resistance is decreased and speed for breakdown torque is shifted towards higher speed. The speed of the machine is always between actual breakdown torque speed and synchronous speed. Operation between slip=1 and breakdown torque or stall during starting is not allowed.

Normal protective relays are designed for use with squirrel cage machines and this must be taken into account in settings.

Note! Failure in starting the machine without checking the adjustments of the complete slip ring gear can result in serious damage! Also connections to the starter and functions with it shall be checked! If the machine is equipped with brush lifting device, read the Chapter “Slip Ring Unit with Brush Lifting Device”.

Brush lifting device must be in starting position before starting the machine.

5.2 Checks before test start

Before the test start can be done, the following checks and measures must be made:

- Sleeve bearing oil reservoir and possible oil supply system are filled with recommended oil to correct level. Oil supply system is turned on.
- The rotor is turned and bearings are listened for abnormal slip noises (to turn a sleeve bearing rotor a simple lever arm is needed).
- If the coupling half is not assembled, the shaft end key is locked or removed.
- In case of water cooled machines the water is turned on. The tightness of flanges and the cooling unit is checked.

The first start should last only about one second. During that time check the direction of rotation of the machine and possible external blower motor and ensure that no obstacles are deterring free running of the machine. In case of sleeve bearings, check that stationary parts do not touch the rotating parts.

Check that the brushes on the slip rings are not sparking.

After the initial test start, the machine can be run for a longer time. Check the temperatures of the stator winding phases and bearings. Check the lubrication of antifriction bearings and oil level or pressure and flow if the machine has sleeve bearings. In case of deviations from normal operation, e.g. elevated temperature, noise or vibration, disconnect the machine. Establish cause and consult manufacturer if necessary. Do not ever defeat protective devices.

6 The first start

When all procedures described in previous Chapters have been made and the test start is made, connect the coupling and start the machine.

6.1 Supervision and maintenance during the first start

Factors essential for the operation of the machine need to be checked regularly. These factors include machine load, cooling and functioning of the bearings.

Record all maintenance and service performed on the maintenance card or in a computer file. The temperature readings given by the probes, placed in the windings and possibly in the bearings, need to be checked frequently to ensure that they remain below the maximum limits. Compare the load current with the value given on the rating plate of the machine to check the operating conditions of the machine.

> **Note!** When RTD´s or equivalent are not available surface temperature at bearing area shall be measured if possible. Bearing temperature is approximately surface temperature +10°C (50°F).

6.1.1 Machines with antifriction bearings

In case of a newly installed machine or a machine which has been out of service for a longer time, inject new grease immediately after the start-up. New grease must be injected when the machine is running until the old grease or excess new grease is discharged through the lubrication valve in the bottom of the bearing housing.

The temperature of the bearings will initially increase because of the excess grease. After few hours the excess grease will be discharged through the lubrication valve and the temperature of the bearing will return to normal.

Measure the SPM-values from the SPM-nipples after the machine has been running for several hours and record them for future use as reference values.

6.1.2 Horizontal machines with sleeve bearings

After the start-up, check that the stationary parts do not rub against the rotating parts. Pay also attention to the oil tightness of all connections. A bearing inspection after running on load for some hours during commissioning or after changing shells or segments still represents the best measure to prevent damage.

The rotation of the lubrication ring is verified through the inspection window on top of the bearing. Check the temperature and the oil level continuously in the beginning.

In force lubricated machines, the oil pressure is adjusted with the pressure valve and orifice. The normal pressure is 125 kPa ± 25 kPa (18 psi ± 4 psi). This gives the right flow of oil to the bearing. Too high oil flow can cause oil leakages to the machine or environment. The rate of oil flow is given in the dimension drawing.

> **Note!** The lubrication system should be constructed so that the pressure inside the bearing is equal to atmospheric pressure. Pressure from the oil pipes (inlet and/or outlet) will cause oil leakages to the machine or environment.

6.2 Vibrations

If noticeable vibration is detected, measure the vibration from the bearing cover or the end shield from both ends. Compare the measurements to the values written in the commissioning report or in the prescribed standard. It is useful to analyse the different frequencies of the vibration, speed and twice the net frequency. See Chapter "Maintenance".

Chapter 6 - Operation

Chapter 6 - Operation

1 General

To ensure trouble free running a machine must be looked after and carefully supervised. In case of deviations from normal operation - e.g. elevated temperature, noise, vibration - disconnect machine, if in doubt. Establish cause and consult manufacturer if necessary. Do not ever defeat protective devices.

2 Number of starts

Check always before starting that no shut-down means have been forgotten and that the cooling system and bearing lubrication are functioning.

The recommended maximum number of start-ups is 1000 a year. Depending on the machine characteristics and starting conditions, even higher values are allowed. Too many and too heavy frequent starts can cause abnormally high temperatures and stresses accelerating ageing and resulting in abnormally short lifetime.

3 Supervision

The operating personnel shall inspect the machine frequently. The purpose of the inspection is to thoroughly familiarize personnel with the equipment. This is imperative if abnormal occurrences are to be detected.

The following inspections must be done in conjunction with Checklist 6 in Chapter “Checklists”.

3.1 Bearings

- Check the bearing temperature.
- Look after that antifriction bearings are re-greased according to instructions on lubrication plate. The possible grease collector box should be emptied every third relubrication time.
- Check the sleeve bearing oil level and functioning of the oil ring (through a sight glass on top of the bearing). Observe time-limit for oil-change and if equipped with oil supply system make sure the system is working. Check that there is no oil leakage.
- Measure the vibration levels. Vibration severities in the "satisfactory" range ($V_{rms} \leq$ 4.5 mm/s) according to ISO 3945 are acceptable in coupled-mode operation.
- Measure the SPM-values and compare them with earlier measurements to observe the development of trend (machines with antifriction bearings).
- Feel the bearing for abnormal noises or surface temperatures.

> **Note!** When RTD´s or equivalent are not available surface temperature at bearing area shall be measured if possible. Bearing temperature is approximately surface temperature +10°C (50°F).

3.2 Cooling

- Check the temperature of the stator winding.
- Observe if the flow of cooling air is normal.
- Observe if the flow of cooling water is normal.

> **Note!** The cooling air must be clean and free of corrosive materials. If the cooling air contains dust, clean the cooling surfaces (ribs, tubes etc.) of the machine and cooling unit regularly.
>
> Even if the cooling water filter is used, some fouling of the cooling coil will occure. Clean the coil regularly.

3.3 Slip ring unit

- Follow the wear of the carbon brushes and change them before the wear limit is reached.
- Check that the brushes are not sparking.
- Ensure that the ring surfaces are smooth. If not, the slip rings must be turned on a lathe. Under ideal conditions an even layer of brown patina will form on the slip rings during the first few hours of operation.

- Change or clean the cooling air filter of the slip ring unit regularly.
- Clean the slip ring housing, slip ring gear, slip ring assembly and possible heat exchanger/upper cover regularly. See Chapter “Maintenance” for instructions. If the machine is equipped with brush lifting type slip ring unit, follow the instructions presented in Chapter “Slip Ring Unit with Brush Lifting Device”.
- Check the tightness of the slip ring housing, water, grease, dust should not enter inside housing.

3.4 Miscellaneous

- Measure the vibration levels on the machine frame and coverings.
- Check the machine for abnormal noises or surface temperatures.
- Observe alarms and fault indications.
- Check that the drain plugs are in open position (half of the plug inside and half outside). Remove possible jam.

4 Follow-up

Normal supervision of operation includes logging of operating data such as load, temperature etc. The comments and data are used as a basis for maintenance.

During the first period of operation (24 hours) supervision should be intensive. Read the temperature of winding and bearings every hour. Check also load, current, cooling, lubrication and vibration.

During the next period of operation (first week) supervision should be done every 24 hours.

During normal use machine checking must be done in conjunction with the regular inspections, the maintenance of the driven machine or during the relubrication.

Chapter 7 - Maintenance

Chapter 7 - Maintenance

1 Bearings and lubrication

1.1 Antifriction bearings

1.1.1 Bearing constructions

Deep groove ball bearings in both ends is a standard construction for horizontal AMK machines. Cylindrical roller bearings are used in the D-end if the machine is loaded with great radial forces. Vertical machines are normally equipped with deep groove ball bearing in the D-end and single-row angular contact ball bearing in the N-end. Complete bearing identification code is stamped on the lubrication plate and dimensional drawing. Different constructions are presented in Chapter “Appendices”.

The D-end bearing is axially fixed in horizontal machines when deep groove ball bearings are used in both ends. The thermal growth will happen towards the N-end. If a cylindrical roller bearing is used in the D-end, then the N-end bearing is axially fixed and the thermal growth will happen towards the D-end. This should be considered when adjusting the coupling.

The bearing in the N-end is axially fixed downwards in vertical machines. The thermal growth will happen in the D-end. This should be considered when adjusting the coupling and moving the machine.

1.1.2 Lubrication technique

Bearings are lubricated by injecting grease to greasing nipples at both ends of the machine. Grease is penetrated to the inner side of the bearing through the grease passage. After filling the free space in the bearing, excessive grease will be discharged out from the opening in the bottom of the bearing construction.

The greasing nipples must be cleaned well before lubricating to prevent dirt from entering the bearings. The grease pump gun should be filled up completely, leaving no air bubbles in the grease. The grease must be free from impurities and water.

The lubrication must be done while the machine is running normally. Otherwise the grease will not penetrate to the bearing equally.

Note! Inject new grease until old grease or excessive new grease is discharged out from the bearing.

In special case the lubrication can be done while the machine is not running. Then the recommended amount of grease is injected to the bearing 3 times. The machine is started for couple of seconds between injections.

1.1.3 Lubrication intervals and recommended greases

Lubrication interval and the amount of grease are stamped on the lubrication plate. Standard intervals and amounts can be read from Tables 1 and 2.

Note! Re-lubrication must be done at least once a year, ignoring the running hours.

Table 1. Relubrication intervals and amount of grease for horizontal machines.

Bearing Type	Amount of grease [g]	Lubrication intervals in running hours at different speeds [rpm]			
		1800-1500	1200-1000	900-750	600-500
6324	70	4400	8800	8800	8800
6326	80	4400	8800	8800	8800
6330	100	3300	6600	8800	8800

Table 2. Lubrication intervals and amount of grease for vertical machines.

Bearing type	Amount of grease [g]	Lubrication intervals in running hours at different speeds [rpm]			
		1800-1500	1200-1000	900-750	600-500
6324	70	2200	4400	4400	4400
6326	80	2200	4400	4400	4400
6330	100	1600	3300	4400	4400
7324	70	2200	4400	4400	6600
7326	80	2200	4400	4400	6600
7330	100	2200	3300	4400	6600

Note! Although the bearings are lubricated at the manufacturer´s work, relubricate new bearings immediately after start-up to ensure a long life time. AMK machines are lubricated in the factory with ESSO UNIREX N3 or MOBILUX EP2, if nothing else is specified.

The lubrication interval on the lubrication plate is based on the bearing running temperature of 70°C (158°F). Size and type of bearings with running speed and mounting arrangement of the machine have also been taken in consideration. The lubrication interval should be halved for every 15 K increase in the bearing temperature. Recommended types of standard greases are listed in Table 3.

If the bearing temperature is noticeably under 70°C (158°F), the lubrication interval can be lengthened to some extent. Other environmental conditions need also to be taken into consideration.

With high temperature grease the lubrication intervals presented in Tables 1 and 2 can be applied up to 85 °C (185°F). Recommended types of high temperature greases are listed in Table 4.

If the ambient temperature may stay below -20°C (-4°F), use grease that is suitable for whole operating temperature range.

Table 3. Recommended standard greases.

Manufacturer	Quality	Thickener	Base oil	Temperature range [°C]	Kinem. visc. of base oil [mm2/s, cSt at 40°C]	Kinem. Visc. of base oil [mm2/s, cSt at 100°C]	Drop point [°C]	Consis-tency [NLGI scale]
ESSO	UNIREX N2	Li-comp.	Mineral	-30 to +165	112	12	300	2
ESSO	UNIREX N3	Li-comp.	Mineral	-30 to +165	112	12	300	3
MOBIL OIL	Mobilith SHC 100	Li-comp.	Synthetic	-50 to +180	100	11	280	2
SHELL	Syntix 100	Li-comp.	Synthetic	-40 to +140	150	21	260	2
SHELL	Alvania Grease G3	Li/Ca	Mineral	-20 to +150	100	11	185	3
NESTE	Rasva 606	Li-comp.	Synthetic	-40 to +150	160	20	>250	1.5
NESTE	Rasva 600	Li-comp.	Synthetic	-35 to +140	120	12	>250	1.5
ELF	Rolexa 3	Li/Ca	Mineral	-30 to +120	110	10	>180	3
ELF	Statermelf EP 2	Polyurea	Synthetic	-40 to +180	84	12	240	2
OPTIMOL	Longtime PD2	Li		-30 to +140	85	9.5	>180	2
TEBOIL	Syntec Grease	Li-comp.	Synthetic	-40 to +140	150	20.0	>260	2
STATOIL	Uniway LiX 42 PA	Li-comp.	PAO	-35 to +150	100	18.0	>260	2
CHEVRON	SRI 2	Polyurea	Mineral	-30 to +150	100	11.0	243	2
KLÜBER	Klüberplex BEM 41-132	Li-comp.	Synt./Min.	-30 to +150	120	14	>220	2
FAG	Arcanol L 135 V	Li	Min./Synt.	-40 to +140	85	12.5	190	2
FAG	L 30	Li-comp.	Synthetic	-50 to +200	162	19.8	>250	2

Table 4. Recommended high temperature greases.

Manufacturer	Quality	Thickener	Base oil	Temperature range [°C]	Kinem. visc. of base oil [mm2/s, cSt at 40°C]	Kinem. visc. of base oil [mm2/s, cSt at 100°C]	Drop point [°C]	Consis-tency [NLGI scale]
MOBIL OIL	Mobilgrease HP 103	Li-comp.	Mineral	-30 to +175	100	11	260	3
KLÜBER	Asonic HQ 72-102	Polyurea	Synthetic	-40 to +180	100	12	>240	2
SHELL	Syntix 100	Li-comp.	Synthetic	-40 to +140	150	21	260	2
CASTROL	LMX	Li-comp.	Mineral	-40 to +150	180		260	2
CHEVRON	SRI 2	Polyurea	Mineral	-30 to +150	100	11.0	243	2
SKF	LGHQ 3	Li-comp.	Mineral	-20 to +150	110	13	300	3

1.1.4 Miscibility of greases

It is important to consider the miscibility of greases if it is necessary to change from one grease to another. If incompatible greases are mixed, the consistency can change dramatically. Then the maximum operating temperature of the grease mix can be so low compared to the original grease, that bearing damage cannot be ruled out.

Greases having the same thickener and similar base oils can generally be mixed without any detrimental consequences, e.g. a lithium base grease can be mixed with another lithium base grease. Calcium and lithium base greases are generally miscible with each other but not with sodium base greases. However, mixtures of compatible greases may have a consistency which is less than either of the component greases, although the lubricating properties are not necessarily impaired.

1.1.5 Control of the bearings when running

One way of detecting bearing damages is to measure the shock pulse generated by impacts as damaged surfaces are overrolled. Measuring devices for this kind of measuring register the rapid sequence of minor shock pulses caused by small irregularities. The curve and shock pulse diagrams represent bearing damage development and how it can be followed with a shock pulse measuring device.

Material fatigue is not the only possible cause for deterioration of a bearing condition and high shock pulse value readings. Bearing condition and life time are largely affected by installation, speed, load, lubrication and other external factors, which also determine the shock pulse value of a bearing.

After commissioning, and when the machine is smoothly running on-load, register the "initial shock values" (SV) of the bearings using a shock pulse tester (e.g. SPM-instrument type T30) or a similar device. Fit the measuring probe to the nipple provided on the end shield. After a certain running-in period, the SV measurement could decrease, i.e. the bearing condition can improve. Therefore, the initial SV measurement should be taken as a reference value for further measurements. Measurements should be taken periodically with same speed, load, measuring points and lubrication conditions, never directly after relubrication.

Compare the new readings with the previously measured values to see if there is any reason to replace the bearing soon. For evaluation of the measuring results, a slide rule has been included in the SPM instrument.

Measuring nipples are bolts that are installed in threaded holes that have a cone-shape ends in the bearing housings. The material is zinc-coated steel.

1.1.6 Monitoring running quality

Another possibility to detect bearing failure by vibration monitoring is to determine typical defect frequencies. Every time a defect is overrolled it causes a peak in the vibration signal. The repetition of these peaks depends on the position of the bearing defect (inner or outer ring or a rolling element, etc.) and the bearing geometry and speed.

The bearing defect frequency peaks generally appear in the lower part of the frequency spectrum (0-2 kHz), usually with harmonics. The frequency depends on the bearing speed, only for rotation speeds lower than 6000 r/min.

The decisive quantity is the rms value of the vibration velocity measured on the bearing housing (according to ISO 3945). Alarm and shutdown limits for automatic control system and for manual measurements should be set as low as possible based on the test results and empirical operating behaviour with the driven machine.

Recommended settings:

ALARM V_{RMS}= 4.5 mm/s
SHUTDOWN V_{RMS}= 7.1 mm/s

> **Note!** The control system should be able to separate occasional shock pulses in the environment that are not related to the machinery system in question, thus making it possible to set the limits to correct level without repeated alarms or shutdowns.

In order to have a comparison with the measured values, the vibration amplitude $\hat{S}$ can be calculated as follows (supposing that vibration is sinusoidal):

$$\hat{S} = \sqrt{2} \times \frac{V_{\text{rms}}}{\omega} = \frac{\sqrt{2}}{2 \times \pi} \times \frac{V_{\text{rms}}}{f} \approx 0.225 \times \frac{V_{\text{rms}}}{f}$$

where

$\hat{S}$ = vibration amplitude [mm]

f = speed frequency [Hz]

A conversion nomograph with limit values is shown in Figure 1.

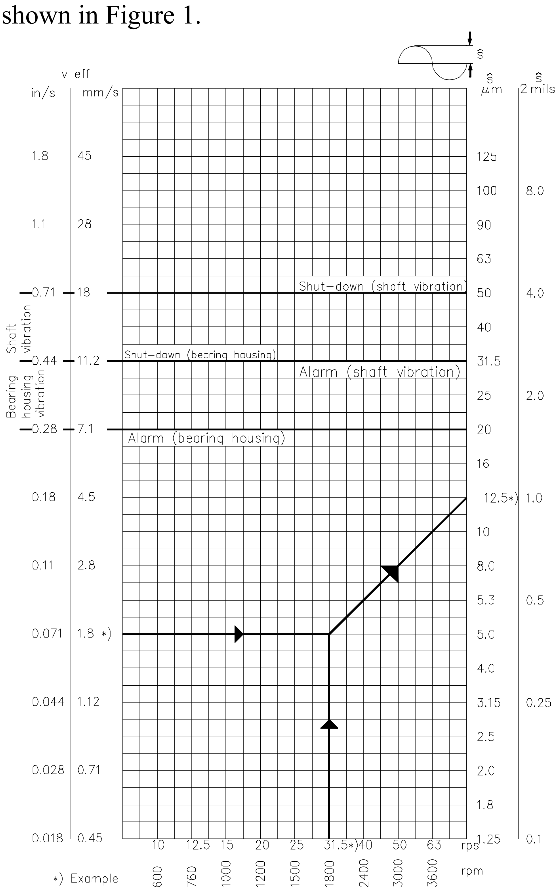


Fig. 1. Conversion nomograph with limit values.

The bearing defect frequencies are in the same range as the low frequency vibrations caused by normal operation of the machine. This is why it is often hard to distinguish these peaks from normal machinery noise.

Use Checklist 7 in Chapter “Checklists”.

1.2 Sleeve bearings

1.2.1 Bearing solutions

The sleeve bearing type used in AMK machines is a side flange bearing (see Chapter “Appendices”). The bearings can be self or force lubricated. The complete bearing type is stamped on the bearing plate of the bearing itself.

The bearings are rigidly mounted to the end shields of the machine. The bearing in the D-end is usually the locating bearing (code B in the type designation). This means that the thermal growth will happen towards the N-end.

The bearing in the N-end is insulated. This means that the inside spherical housing surfaces are lined with nonconducting PTFE film in order to avoid bearing currents (Figure 2).

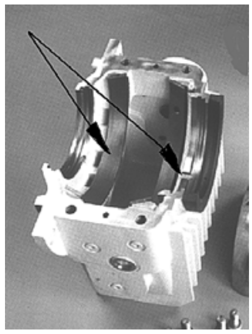


Fig. 2. Insulation films of the sleeve bearing.

The retention stopper in housing, which prevents the bearing shell from dislocating, is surrounded by a nonconducting sleeve. The shaft seals and as well as the temperature sensor connection are made of nonconducting material. Bearings are provided with connections for oil feed, oil drain, thermometer and oil level sight glass.

1.2.2 Recommended oils

Note! Sleeve bearings are delivered without oil. The oil reservoir and possible oil supply system must be filled with recommended oil before start-up. There is enough oil in the bearing if half of the oil sight glass is covered.

The oil used in the bearings must have a viscosity value as defined in ISO 3448 class or SSU. Table 5 presents the typival oil viscosity values.

Table 5. Typical oil viscosity related to rotational speed.

Rotation speed [rpm]	SSU viscosity grade number	ISO viscosity grade number
≧1500	107 SSU/100°F	ISO VG 22
1000 – 1200	214 SSU/100°F	ISO VG 46
≦900	315 SSU/100°F	ISO VG 68

Note! The type of oil that has to be used for lubricating the bearing is given on the lubrication plate and dimensional drawing of the machine.

Table 6 lists the recommended mineral based oils to lubricate the bearings.

Table 6. Recommended oils.

Manufacturer	Quality
BP	Energol CS
CASTROL	Perfecto T
DEA	Astron HL
ESSO	Terresso
FUCHS	Renolin DTA
GULF	Harmony
KLÜBER	Lamora HLP
MOBIL	DTE
NESTE	Paine
SHELL	Tellus Oil S
TEBOIL	Larita Oil
TOTAL	Azolla ZS

Bearing manufacturer has tested some synthetic oils with good results. With these oils it is possible to run the bearing at higher operating temperatures and the alarm and trip limits can be set higher respectively.

Note! Contact the machine manufacturer for approved synthetic oils and permission to use them with the machine.

1.2.3 Maintenance

Bearing housings has to be kept clean on the outside, since the radiation of heat is reduced by deposits of dust or dirt.

During the first 24 operating hours, the oil flow, possible leaks and the level of vibration are inspected every hour. Changing of a possible oil filter must be done after 1000, 2000 and 3000 operating hours. Changing of oil and cleaning of an oil filter must be performed after 8000 operating hours.

In case of sleeve bearings with separate oil supply system, oil is changed every 20000 operating hours.

Shorter intervals are required in case of frequent starts and stops, high oil temperature or excessive contamination due to external influences. The general condition of the oil will provide information in this respect.

The housing is drained through the oil drain hole which is located centrally in the bottom of the bearing. Filling is effected through the bore of the sight glass which can be removed using an adjustable face spanner.

When changing out the oil, special care should be taken to rinse out contamination and to remove oil sump residues (if possible, the oil should be drained while the bearing is still warm). If unusual alterations of the oil or extra-ordinary residues are noted, it is paramount to investigate and, if possible, to remove the causes for this before putting the bearing into operation again. If chemical detergents are used they have to be completely removed when the cleaning process is finished.

For filling and re-filling use the same quality of oil as specified for the application. The dimension drawing should be referred for the relevant indications.

To check the quality of oil, oil analyses should be performed regularly. An oil analysis performed by mineral oil companies may form the basis for decisions as to whether the oil in the bearing is still suitable for use.

1.2.4 Monitoring running quality

A possibility to detect bearing failure by vibration monitoring is to determine the typical defect frequencies.

Alarm and shutdown limits for automatic control system and for manual measurements should be set as low as possible based on the test results and empirical operating behaviour with the driven machine.

The decisive quantity is the rms value of the vibration velocity measured on the bearing housing (according to ISO 10816). Recommended settings:

ALARM V_{RMS}= 4.5 mm/s
SHUTDOWN V_{RMS}= 7.1 mm/s

Note! The control system should be able to separate occasional shock pulses in the environment that are not related to the machinery system in question, thus making it possible to set the limits to correct level without repeated alarms or shutdowns.

Recommended maximum settings for relative shaft vibration are:

ALARM V_{RMS}= 7.1 mm/s
SHUTDOWN V_{RMS}= 11.2 mm/s

In order to have a comparison with the measured values, the vibration amplitude S can be calculated as follows (supposing that vibration is sinusoidal):

$$\hat{S} = \sqrt{2} \times \frac{V_{rms}}{\omega} = \frac{\sqrt{2}}{2 \times \pi} \times \frac{V_{rms}}{f} \approx 0.225 \times \frac{V_{rms}}{f}$$

where

$\hat{S}$ = vibration amplitude [mm]
f = speed frequency [Hz]

A conversion nomograph with limit values is shown in Figure 1.

Bearing defect frequencies are in the same range as low frequency vibrations caused by normal operation of the machine. This is why it is often hard to distinguish these peaks from normal machinery noise.

1.2.5 Inspections

Inspections are carried out as a part of the preventive maintenance work. Inspections are also necessary if the bearing temperature increases clearly by several degrees or if the lubricating oil alters strikingly.

For an inspection it is sufficient to remove the top part of the bearing while the bottom part may be left on the machine. The bearing and the work place are cleaned thoroughly before disassembling.

Use Checklist 7 in Chapter “Checklists”.

2 Heat exchangers

Air-to-air cooled machines are equipped with tube type heat exchanger, which is placed on top of the machine (also on top of permanent contact type slip ring unit), does not have to be dismantled for cleaning. Possible noise damper and air duct must be removed before cleaning. Dust and dirt can be removed using a soft round brass wire brush, which is pushed through each tube. Steel wire brushes should not be used, because they are too hard and can damage the tubes.

Air-to-water cooled machines are equipped with a cooling coil. During the initial period of operation, the coil should be inspected frequently. Check the water flow and tightness of connections.

Even if water filter is used, some fouling of the cooling surface and the tube wall will occure. This fouling reduces the cooling capacity. The cooling coil should therefore be cleaned at reqular intervals, depending on the property of the water. Measures should be taken to repair any damage, due to corrosion, that may have occurred in the tubes or the water chambers.

Drain the coil thoroughly. Remove the headings, chambers and mark up the location of the chamber to secure a correct mounting. Clean the inside of the tubes by using the brush and flush with water. Remove the old gasket and clean the inside of the chamber.

3 Filters of an upper cover

Upper cover of the standard weather protected machine can be delivered with or without filters according to customers specification. By special order, the upper cover is equipped with a differential pressure switch for monitoring the condition of the filters. The filter should be changed immediately after alarm. It is also higly recommended that the operating personnel manually inspect the filters frequently.

How often the filters are changed depends upon the cleanliness of the air in the surrounding environment. If surrounding air is sufficiently clean, the filters can be changed during operation.

> **Note!** Remove the filters from the machine before cleaning them.

Filters are washable. A stream of water or cleaning solution can easily reach and flush out collected dirt.

4 Slip ring unit

The slip ring housing should be kept clean, the doors closed and inspected at regular intervals. It is not recommended to any maintenance work when the machine is running.

> **Note!** If gaskets of the slip ring housing have to be changed or lubricated, do not use any silicone based material e.g. silicone rubber, silicone plastic or silicone grease.

4.1 Permanent contact type slip ring unit

4.1.1 Changing of the carbon dust filter

The slip ring unit of the permanent contact type is equipped with filter for carbon dust (4, 6 and 8 pole machines only). The cleaning interval of the filter in respect to carbon brush wear is shown in Figure 3.

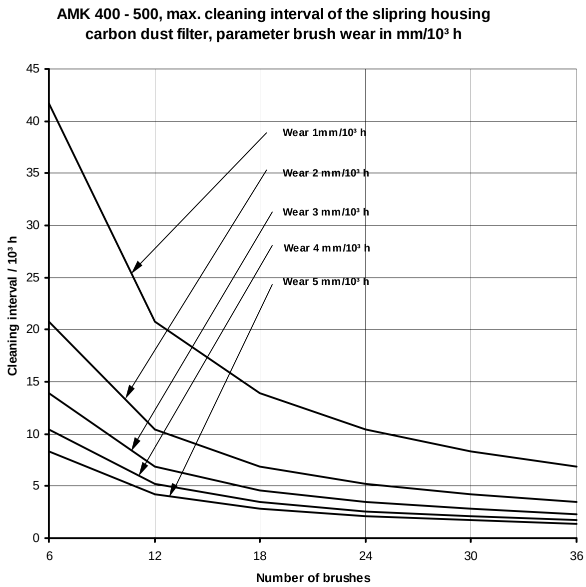


Fig. 3 Interval for cleaning the filter.

4.1.2 Cleaning of the slip ring unit

Carbon dust as result of brush wear should be cleaned from all insulated slip ring gear and brush pin parts at regular intervals. The cleaning interval is about one month, depending on the number of carbon brushes and the operating conditions. The dust can be brushed off with a dry brush, blown away with dry air, or wiped off with a clean cloth slightly moistened with methylated spirit.

It is recommended to clean at shorter intervals during the initial operating period of the motor until a suitable cleaning frequency interval is established. Neglect in complying with these maintenance requirements may result in dust bridge formation and tracking between live parts.

4.1.3 Checking and changing of brushes

All carbon brushes and brush-holders must be inspected at regular intervals.

The brushes must slide on the surface of the slip rings with their entire cross sectional area with a pressure of 2 N/cm². Helically grooved slip rings have a brush contacting surface of about 60% of the brush cross sectional area. However this reduction of the contact area needs not to be taken into account, i.e., the brush pressure is applied onto the whole brush crossection area. The contact surfaces should be completely clean, shiny, and smooth. The slip rings should be free of oil and grease, and after a few hours operation, an even layer of brown patina should form on them. Worn brushes must be changed before the top plate begins to bear on the brush-holder guide, or before the wear mark on the brushes has been reached.

> **Note!** New brushes must be of the same quality as those originally supplied with the motor, and should be fitted one at a time for each slip ring.

If the slip rings are turned on a lathe, the brush-holders will require resetting to give a gap of about 2 mm between the slip rings and the brush-holder.

> **Note!** Remove all brushes before cleaning. Brushes should never come into contact with the cleaning solvent or the solvent vapour.

4.2 Brush lifting type slip ring unit

Follow the instructions presented in Chapter "Slip Ring Unit with Brush Lifting Device".

5 External blower motors

The external blower motors are maintenance free units, e.g. the bearings of external blower motors are greased for life. A spare external blower motor is recommended. The maintenance of the blower motor is performed according to motor`s manual.

6 Windings

6.1 Need and scope of maintenance

The windings of rotating electrical machines are subject to electrical, mechanical and thermal stresses. The windings and insulation gradually age and deteriorate due to these stresses. Therefore, the service life of the machine often depends on the insulation durability.

Many processes leading to damages can be prevented or at least slowed down with appropriate maintenance. Windings in small AC-machines usually require only minor maintenance. The guidelines and instructions in this section of the manual are valid for the maintenance of windings in all large AC-machines.

6.2 The maintenance program

Principles:

- Maintenance of the windings should be arranged according to other machine maintenance.
- Maintenance is done only when necessary.

An important machine should be serviced more often than a less important one. This also applies to windings that become contaminated rapidly, and to heavy drives.

Table 7 is an example of a simple maintenance scheme. Users should, however, plan the maintenance program according to their machines, conditions, and processes.

Table 7. Maintenance scheme.

Type of machine	Inspection interval	Maintenance
1 Heavy drives	Periodic bearing inspection.	Check the temperatures and vibration. Clean the outer surface if necessary.
	Once a year.	Open, inspect, clean, tighten supports, re-varnish if necessary.
2 Form wound LV and HV machines	Every third bearing inspection.	Check the temperatures and vibration. Clean the outer surface if necessary.
	Every three to five years (when changing the bearings).	Open, inspect, clean, tighten supports, re-varnish if necessary.

6.3 Exterior inspection

The correct temperature of the windings is ensured by keeping the exterior surfaces of the machine clean and by monitoring the temperature of the cooling agent. If the cooling agent is too cold, water may condensate on the cold water - radiator, and the mixture of cold and warm air might produce mist. This can wet the winding and deteriorate the insulation resistance. The operating temperatures must be monitored with resistance temperature detectors. Significant temperature differences among the detectors could be a sign of a damage in the windings. Make sure that the changes are not caused by the drifting of the measuring channel.

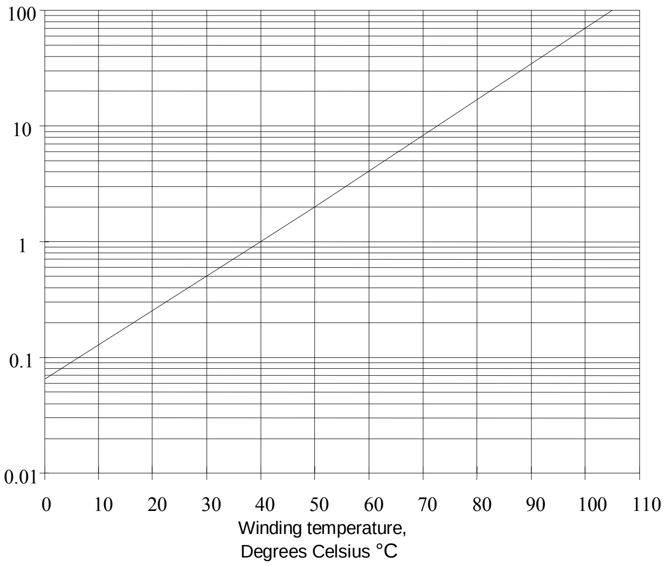
6.4 Maintenance tests

ABB Service in many countries offers a complete service package with several tests.

6.4.1 Insulation Resistance Test

Purpose: The insulation resistance values supply information on wetness and degrees of contamination in the insulation. With this information, one can prepare the necessary cleaning and drying actions.

Method: When the nominal voltage of the tested machine is less than or equal to 3 kV, the test voltage is usually between 500 and 1000 V DC. If the nominal voltage of the tested machine is higher than 3 kV, the test voltage is usually between 1000 and 2500 V DC. The insulation resistance values are noted at fifteen seconds and one minute or at one minute and ten minutes.



The Polarization Index (PI) is given by the relation:

$$PI = \frac{R_{1\min}}{R_{15s}} or (\frac{R_{10\min}}{R_{1\min}})$$

Effect of Temperature: The insulation resistance usually decreases sharply due to the temperature rise. This is shown by the coefficient K_t in Figure 4. By measuring the winding temperature, one can determine the coefficient K_t from the graph below. By multiplying this coefficient K_t with the measured insulation resistance of the winding R_m, the corresponding insulation resistance at a standard 40°C, R40°C, is determined:

(1) $R_{40°C} = K_t \times R_m$

Fig. 4. Correlation between the insulation resistance and the temperature.

Table 8. Temperature values in degrees Celsius (°C) and degrees Fahrenheit (°F).

°C	0	10	20	30	40	50	60	70	80	90	100	110
°F	32	50	68	86	104	122	140	158	176	194	212	230

The polarization index is less dependent on the temperature than the insulation resistance. When the winding temperature is below 50°C (122°F), it may be considered independent of temperature. High temperatures can cause unpredictable changes in the polarization index, so it should not be used above 50°C (122°F).

Effects of dirt and humidity: The dirt and humidity accumulating in the winding normally reduce the insulation resistance and the polarization index as well as their dependence on temperature. Thus, the line from Figure 4 becomes less steep. Windings with open creepage distances (e.g. from squirrel cage) are very sensitive to the effects of dirt and humidity.

Acceptable values: There are several rules of thumb for determining the lowest insulation resistance value with which the machine can be safely started. The probability of insulation failure increases as the insulation resistance deteriorates, but an absolutely safe value of insulation resistance does not exist. Although the insulation resistance value may be high, conducting dirt collecting on one spot of the creepage surface risks failure. In the US. [1], the following equation is used for determining the minimum acceptable insulation resistance at 40°C:

(2) $R_{40°C} = 1 + U$ [MΩ]

where U = main voltage [kV]

This value is compared with that determined from Eq. (1) and insulation measurements. Insulation resistance values for machines serviced at ABB Service are determined using a standard temperature of 80°C instead of 40°C as shown in the following equation:

(3) $R_{80°C} = 1 + U$ [MΩ]

where U = main voltage [kV]

The polarization index values usually range between 1 and 4. When the windings are humid and dirty, the PI is approximately 1.

As a thumb rule the following minimum values may be applied to the PI:

- for class A machines PI = 1,5
- for class B-F machines PI = 2,5

where PI = $\frac{R_{1min}}{R_{15s}}$.

The PI is seldom used anymore because it occasionally gives misleading values. For instance, some very low PI values have been measured with modern epoxy-mica insulations although the windings have been dry and the insulation resistance high (thousands of MΩ). When estimating a machine's ability to start after a standstill, the insulation resistance is more important than the polarization index.

6.4.2 Voltage Test

A voltage test is used to check for electrically weak spots in the windings that may lead to insulation failure during servicing. It is carried out with greater maintenance work and repairs. DC or AC voltage is used for the over voltage test. DC voltage tests, although seldom performed, use 1,6 times the root-mean-square value of the AC voltage. AC voltage tests use the following test voltages:

- for service and repair

  1,2 x U + 400 [V]

- for periodical tests

  1,5 x U [V]

where U = main voltage (V).

> **Note!** The higher voltage test is always used for modern epoxy-mica insulations.

6.4.3 Tan delta-measurements

Tan delta, representing the dielectric and discharge energy losses, is measured in steps of 0.2 x U up to the main voltage U. The rate of rise of tan delta as a function of voltage describes the average partial discharge level both inside and on the surface of the insulation. This makes it difficult to determine the condition inside the insulation. It is emphasized that tan delta measurements can not estimate the age or predict failure of the insulation.

6.5 Inspection

6.5.1 Observations

Winding inspections reveal information about:

- the rate of contamination; presence of dirt and humidity
- radiator condensation and leakage
- stability of bracings, vibration marks, and cracking
- marks of overheating.

All inspections should be recorded on the enclosed maintenance form.

When examining the contamination, particular attention should be paid to the open creepage surfaces, as the insulation resistance is easily affected by the dirt accumulating there.

Accumulating dirt blocking coil gaps and air ducts diminishes the cooling capacity of the machine. As a result, the winding temperature increases, and the ageing may speed up considerably.

Mechanical strain, vibration, and shocks may produce cracks on the edges of the supports, tyings, and around slot ends. Loose supports and slot wedges are signs of further deterioration. Abrasion marks and powder near the supports, tyings, and at the slot ends, must be checked. Complete loosening of the slot wedges and bent coils are serious problems that must be rectified immediately.

Hair cracks and fractures in metal parts such as supporting bolts and squirrel cage windings are also signs of deterioration, but they take longer to develop a failure.

Humidity in the winding is often shown by the marks it leaves behind: rust on iron, drop marks, dripping, and wetting marks on dirt layers. Bush-like patterns, often charred and left behind by the tracking currents, warn of an approaching failure. In rare cases, conductors are corroded.

Marks of the electrical effects (apart from tracking current marks), are usually hidden inside the slot and conductor insulations.

Short period overtemperatures can leave marks all over the machine. Copper in the squirrel-cage windings grows darker (darkening may also be due to the gases in the environment), and it oxidizes. Core laminations of the rotor become blue (over 350°C [662°F]) if the temperature rises due to a jam or an exceedingly heavy start.

Prolonged period overtemperatures cause premature ageing. The insulating materials become brittle and darken in the early stages, especially varnishes containing cellulose. As a result, the windings split, disintegrate, and fracture.

6.5.2 Conclusions of the actions

According to the observations the following conclusions can be drawn for necessary actions (table 9):

Table 9. Observations and actions.

Observation	**Action**
Degree of contamination	
– a lot of dirt, cooling ducts about to be plugged	– cleaning, and drying, if necessary
– conductive dirt, low insulation resistance	– cleaning, and drying, if necessary
– humidity, low insulation resistance	– drying
Finishing varnish	
– mat, worn, cracked	– cleaning and re-varnishing
– coming off	– remove old varnish and re-varnish
Supporting parts	
– loose slot wedges	– tightening *)
– vibration marks	– tightening, strengthen and re-varnish *)
– bent coils	– strengthen or redo winding *)
Ageing	
– darkening, slight embrittlement	– cleaning and re-varnishing
– embrittlement, loose insulation layer	– redo windings
	*) A statement from an expert is needed.

6.6 Cleaning the windings

Accumulating dirt in the open creepage surfaces should be removed. This is especially important when re-varnishing the windings because a new varnish coat will trap any existing dirt beneath the new coat.

6.6.1 Cleaning methods

Blowing and vacuuming

Blowing and vacuuming are used if the dirt is dry and can be removed easily. Vacuuming is recommended, since blowing tends to redistribute the dirt or move it deeper between the insulation layers.

Wiping

Wiping is used when spray-wash is not possible. Surfaces easily reached are wiped clean with a cloth dampened with detergent. In cramped areas of the windings, a special brush may be more effective.

Spray wash

A spray wash is carried out with an airless high-pressure spray or a conventional spray. The high-pressure spray is more effective in removing dirt. The detergent used should remove the dirt without softening or damaging the insulation. Use excessive amounts of the cleaning agent.

Dip wash

A dip wash can be used if the detergent does not soften or damage the insulation. Since the dirt is not removed mechanically in this method, a very effective cleaning and scouring agent is needed. A long dipping time may be required.

Water wash

A water wash involves rinsing with water to prevent the detergents from penetrating into places where they can not be removed. A water wash is done if needed following the instructions given above for wiping, dip wash, or spray wash. The detergents used are described in Section 6.6.2.

After washing, the windings are rinsed with pure water several times. It is recommended to use distilled or deionized water for the last rinse.

Drying after the water wash is necessary (see Section 6.6.3).

6.6.2 Cleaning agents

Some features of the detergents are described in table 10.

Before any cleaning agent is used, its damaging effect on the old winding surface should be checked. A suitable test can be performed as follows:

Using a cloth wet with the cleaning agent, rub the surface to be tested for five minutes. Make sure that the surface remains completely wet during this time. After rubbing, try to remove the finishing varnish by thumb nail. For comparison, do the same thing to a dry part of the surface. If the surface layer is soft or removed easily, the cleaning agent is too strong.

For minimal environmental loading, water or water-detergent mixtures should be used when possible. If the dirt contains water soluble agents, water must be used.

Substances that improve the cleaning power should be added to the water to dissolve grease-containing dirt. These detergents should not leave electrically conductive residues on the surfaces.

Water soluble solvents such as acetone and isopropyl alcohol can also be used to improve the cleaning effect. Note that such solvents increase the flammability of the mixture.

If organic solvents must be used, cleaning agents based on aliphatic hydrocarbons are recommended. Several manufacturers of cleaning solvent mixtures are presently developing such halogen-free cleaning agents to replace the chlorinated solvent mixtures used in the past.

White spirit is the most common organic solvent. It is a good solvent for greases but quite inefficient for pitch-like dirt on the windings (produced by coal and burning residues of diesel oil and humidity). White spirit is also flammable (flash point 30...40°C [86...104°F]). The cleaning capacity of white spirit can be improved by adding 1.1.1-trichlorethane to the solvent, however, the use of chlorinated solvents is no longer recommended.

6.6.3 Drying

The windings must be dried after a wash (especially a water wash and rinse) or if they have become humid in use or during a standstill.

The rate of temperature rise of the winding should not exceed 5 K (9°F) per hour, and the final temperature should not exceed 105°C (220°F). A sudden temperature rise or a too high final temperature can cause steam to be formed in the cavities of the windings, which in turn can destroy the windings. During the drying process, the temperature should be monitored periodically, and the insulation resistance should be measured at regular intervals.

A very wet machine should be dismantled and the winding dried in the oven. Every part should be checked. If the machine is not very wet, the winding can be dried by passing a current through it.

If the winding is dried by passing current through it, the source of electricity could be a welding generator or a similar device.

Note! When an electric current is used for drying the windings, the rotor must be first removed from the machine. Direct current or alternate current can be used. Current cannot exceed 25 % of the value of the nominal current, which is indicated on the rating plate on the machine.

When drying in an oven, the temperature rise and the maximum temperature should be monitored carefully. The oven temperature should be 90°C (194°F) for 12 to 16 hours and then 105°C (220°F) for six to eight hours.

Effective drying is achieved with the proper balance of heat and ventilation. The air inside the machine should be circulated in the most effective way.

Drying in an oven with good ventilation is the most effective technique. Unfortunately, this is not usually possible at the machine's operating site. Therefore, either hot-air-blow or heating the windings with current should be used. Adequate fresh-air exchange is essential, whatever heating method is used.

The drying of the windings should be followed by insulation resistance tests. At the beginning of the drying treatment, the insulation resistance decreases due to the temperature rise. As the drying continues, however, the insulation resistance increases until it reaches a stable value.

6.7 Varnishing of the windings

A finishing varnish is a varnish or a resin coat that is sprayed or brushed on the insulation. It is a protective layer that seals the windings, improves tracking resistance somewhat and makes cleaning easier. In new machines finishing varnish treatment is made optionally.

The finishing varnish may after long operating time crack or peel off to certain extent. This can be corrected by giving the windings a new coat of finishing varnish. Re-varnishing is necessary when:

- the old finishing varnish flakes, cracks or peels off,
- the surface of the winding is rough (dirt sticks to it easily)
- the materials on the surface of the insulation or tyings have moved.

The windings should be cleaned with utmost care before a new coat of varnish is given so that no dirt will be left under this new coat of varnish. Old finishing varnish that can come off easily should be removed.

Varnish is usually applied with a spray (one or two coats suffices). If the windings are still warm after drying, the temperature should be less than 40°C (104°F). One should try to apply the varnish between the coils and other parts that are not easily reached. Thick coats of varnish should be avoided as they dry slowly. Rotating parts should be left to dry at least 24 hours at room temperature before bringing them into use. Solvent fumes from the varnishes are generally poisonous and flammable, so safety at work should be taken into account (see Section 6.10).

Table 10. Features of the detergents for the winding.

Detergent			Water(hot)	Water (hot) +detergent	Isopropylenealcohol	White spirit 140/200	Acetone	Xylene	1.1.1-trichloroethane	White spirit + 1.1.1trichloroethane
Proportion Consistency				1:20 (volume)						1:1 (volume)
Class of flammable liquids			Incombustible	Incombustible	I	II	I	II	Incombustible Not recommended	II Not recommended
Allowed concentration in air, ppm cm^3 / m^3					400	200	1000	100	200	200
DIRT Dissolving or educing effect		Normal dust	2	3	1	3	1	1	2	3
		Greasy coaldust		2	2	3	3	3	3	3
		Greasy woodpulp		2	1	2	2	2	2	2
		Salts	3	3						
		Pitched diesel grime, fats, oils	1	1-3	2	2	3	3	3	1
VARNISH OR RESIN Dissolving of softening effect	Old machines	Aspahlt-varnish	3	3	2	2				1
		Shellack	2	2		2	1			1
		Black glossy finnishing varnish	3	3	2	2				1
		Impregnating varnish	3	3	3	3	1	2	2	3
		Red finishing varnish (epoxy, alkyd)	3	3	3	3	2	2	2	2
		Epoxy, polyester resin	3	3	3	3	3	3	3	3
		Silicone rubber	3	3	3	2		1		2
Commutator (insulations consisting shellack)			2		2					

EXFLANATIONS

Dirt: Empty: Does not clean; 1: Removes dirt poorely; 2: Cleans reasonably; 3: Cleans well

Varnish or resin: Empty: Does not resist the solvent; 1: Poor resistance of solvent; 2: Satisfactory of solvent; 3: Good of solvent

6.8 Other maintenance operations

Some examples of repair maintenance are:

- impregnation
- tightening of the slot wedges
- tightening of the supporting parts.

Determine from the manufacturer if these operations are necessary. If they are, obtain a detailed plan to carry them out.

6.9 Maintenance of old windings

The old finishing varnish type may be unknown. When choosing the cleaning solvent, make sure not to damage the old coat of varnish (see Section 6.5.2). Test:

Rub the surface with a cloth moistened with the solvent for a couple of minutes. If the varnish does not dissolve, stick to the fabric, or become soft when tested with a fingernail, the solvent may be used.

Finishing varnish and surface materials may be brittle and the insulations at the coil overhangs may be soft and fragile, so avoid hard pressing or rubbing when cleaning. Finishing varnish that comes off on its own should be removed. Re-varnishing is then generally needed.

When re-tightening the slot wedges, make sure that they are not too tight as the old insulation might get damaged. It is best to fix the slot wedges with an adhesive resin.

When re-varnishing, ask the manufacturer about the impregnation process and the choice of finishing varnish. The type of finishing varnish can be determined by testing a small sample on the old surface and checking the adhesion and quality. For example, epoxy finishing varnish usually adheres well to old bitumen varnish, increasing the resistance of the surface to oil and solvents. Sometimes, it is best to use the original finishing varnish when re-varnishing.

When drying, the construction of winding insulation should be taken into account so that the insulation does not get damaged. Insulations consisting of cellulose and micafolium should be dried slowly. The water vapour should be allowed to escape without causing a high pressure on the insulation, making it swell or break; the highest drying temperature range is 100°C-110°C (212°F-230°F).

6.10 Work safety principles with winding maintenance

Winding maintenance involves:

- handling hazardous solvents, varnishes, and resins,
- dealing with flammable solvents and varnishes,
- testing at high voltage (HV).

Some dangerous substances are:

- white spirit: solvent
- 1.1.1-trichloroethane: solvent
- finishing varnish: solvent and resin
- adhesive resin: epoxy resin

There are special instructions for handling dangerous substances during maintenance work. Important handling instructions can also be found on warning labels of the packing.

Some general safety measures are as follows:

- Avoid breathing air fumes; ensure proper air circulation at the work site or use respiration masks.
- Wear gloves and suitable protective clothing to protect the skin. One should always use protective creams.
- Spray-varnish equipment, the frame of the machine, and the windings should be earthed during spray-varnishing.
- Do not smoke, eat, or drink at the work site.
- Take necessary precautions when working in pits and cramped places.
- Only people trained to do high voltage work can carry out a voltage test.

LITERATURE

1) IEEE Std. 43-1974, IEEE Recommended Practice for Testing Insulation Resistance of Rotating Machines.

2) IEEE Std. 432-1976, IEEE Guide for Insulation Maintenance for Rotating Electrical Machinery.

TEST RECORD		Machine, type	....	No:	....	
Annual inspection	☐	Use	....	No:	....	
Inspection every 4 years	☐	Voltage/output	....	V	....	kW
Random inspection	☐	Running hours	....	h		

Distribution .... Date/inspected by ..../..........................

1. Seals	OK ☐	Observations: ....
2. Fixing air guiding plates etc.	OK ☐	Observations: ....

3. Contamination	Stator windings	Rotor windings	Air ducts	Cooling radiators	Explanations	End D	End N
Total amount of dirt							
Grease, oil							
Dry dirt,dust							
Dampness, rust							

	OK	Observations	D	N
4. Windings				
4.1 AC stator				
Support				
Coils				
Connecting cables				
Core laminations				
4.2 Asynchr. rotor				
Ends of squir. cage windings				
Keys of squir. cage ring				
Core laminations				
5. Fan				
6. Cooling system				
Visible radiator parts				
Inner radiator parts				
Flow-switch				
7.Elect. connections				
Main connection				
Control gear				

8. Electrical test			
Insulation resistance to earth	R_{15} = ... MΩ		R_{60} = ... MΩ
		Winding temperature	
Voltage test 1 min ☐		Test voltage	
Operation test of protection ☐	Voltage .... kV	DC voltage ☐	AC voltage ☐

QUANTITY ESTIMATION

0 = clean
1 = slight
2 = plentiful (ducts about to plug)
3 = very plentiful (ducts plugged)

ESTIMATION BASIS

1 = dropping
2 = loosening
3 = cracking
4 = breaking
5 = dust, caused by vibration
6 = swelling
7 = darkening
8 = embrittlement
9 = water marks
10 = tracking
11 = hair cracks
12 = risen bars
13 = battered
14 = knocking: doubtful
15 = corrosion
16 = leakages
17 = condensation
18 = loose ribs
19 = abrasion
20 = noise from the bearing
21 = another noise. What kind of?
22 = other flaws. What sort of?

7 Maintenance painting

7.1 General

Touch-up painting is sufficient for maintenance when the rusted area is less than 8% of the painted surface that means that the rust grade is Ri1 – Ri3 (ISO 4628 and SFS 3762). Damages caused by transport or installation may also be repaired by touch-up painting.

Repainting is necessary for maintenance when the rusted area is 8% or more (the rust grade is Ri4 or Ri5).

7.2 Touch-up painting

If it is not possible to blast clean steel surfaces to Sa 2.5 (SFS-ISO 8501-1) in accordance with the original paint system, it is recommended to use the following paint system.

7.2.1 Surface preparation

Remove any solid impurities. Remove water-soluble salts, grease and oil using an alkaline solution or emulsions. Wash the surfaces thoroughly with water.

Remove all loose paint. Remove rust by power tool or wirebrush cleaning to minimum St 2 - the best result is achieved by blast cleaning. (SFS-ISO 8501-1). Level off the edges between the old paint film and cleaned up areas. When using blast cleaning, be sure that there are no cracks in the remaining paint film and do not cause damage for the sealings.

The surface preparation is in accordance with the following standards:

- SSPC-Vis 1-82
- SFS-ISO 8501-1:1994 (SS 05 59 00) St 2, Sa 1

SSPC = Steel Structures Painting Council

SO = International Standards Organisation

SFS = Finnish Standards Association

If the entire surface has to be overcoated, abrade the old topcoat to a rough finish and remove all dust and other cleaning residues.

7.2.2 Application conditions

Surface must be dry. The temperature of the ambient air, surface or paint should not fall below +10°C / 50°F during application and drying. Relative humidity should not exceed 80%. The surface temperature of the steel should remain at least 3°C / 5°F above the dew point.

7.2.3 Application

Touch-up painting should be done by brush or airless spray. Mix first the base and the hardener separately before mixing the components together. Total film thickness should be the same as for the original paint system. If the film thickness exceed 200 µm, application should be done with 2 layer and both layers should have the same thickness.

The topcoat is not necessity but it can be used if outward appearance is important. The standard colour is blue (RAL–ASEA C, TVT B-062, Munsell 8B 4,5 / 3,25, NSC 4822-B05G).

Surface treatment:

2-component high-solids, modified epoxy aluminium paint (e.g. TEMASTIC ST 200), 100 – 200 µm.

2-component high-solids, modified epoxy aluminium paint (e.g. TEMASTIC ST 200) (only if necessary), 100 – 200 µm

2-component epoxy or polyurethane topcoat (not necessity).

7.2.4 Repainting

When the rusted area exceed 8 %, the entire coating must be renewed. Remove the old paint film and blast clean to Sa 2.5. Recoating in accordance with the original paint system.

7.2.5 Standards of the painting system and surface preparation

TP26 - EPUR 180/ 2 - Fe St2

Steel, cast iron and parts made of hot-rolled steel:

SFS 4596: E 180-320/ 1-2 - Fe St2

SFS 4596: EPUR 180-320/ 2-3 - Fe St2

Parts made of cold rolled sheet or light metal:

SFS 4962: E 180-320/ 1-2 - Fe St2

SFS 4962: EPUR 320/ 2-3 - Fe St2

- EPUR 320: epoxy undercoating, polyurethane finish nominal film thickness 320 µm
- Fe: surface material
- St2: wire brushing to the degree 2

- Sa2.5: sand blasting to the degree 2.5

ISO 12944-5 / paint system 5.13 and 7.03.

8 Cleaning

Before beginning the cleaning work, the machine should be partially dismantled (as far as practical). Components of austenic steel can be destroyed by stress corrosion if halogenous cleaning solvents are employed. Therefore, electrical machines should only be cleaned with non-halogenous solvents. Mechanical dry cleaning should be used first, "to get the worst off". Wet cleaning methods should only be used for the main cleaning, after thorough application of a mechanical cleaning method. Standard cleaning agent, industrial benzene, should be used for ordinary dirt and xylene may be required with very gummy oil.

9 Overhaul

When carried out at set intervals, every 2-4 years are recommended, overhauls allow supervision of wear, early recognition of any sign of damage and replacement of defective parts in time. The extent of overhaul will be mostly determined by the observations made during operation. All inspection and dismantling /reassembly work is to be performed by suitably trained personnel. The first overhaul should be performed after 500 starts or 8000 hours of operation whichever occurs first, but not later than 2 years of operation.

Chapter 8 – Dismantling and Reassembly

Chapter 8 – Dismantling and Reassembly

1 In general

This chapter presents the procedure to dismantle and reassemble the machine. Operations must be carried out by skilled persons with knowledge to follow the applicable part of the instructions for the extent of maintenance work in question. Constructional drawings in Chapter "Appendices" help to follow the work items.

> **Note!** Before any action the incoming cables shall be separated from electric power network and grounded. All auxiliary cables shall be disconnected. (mark each cable and wire before disconnecting them). Follow all necessary safety precautions according to the regulations governing the work.

Notice that for certain maintenance work e.g. change of the slip ring gear, only partial dismantling of the slip ring housing & accessories is needed.

> **Note!** Some customer specific items may not be included in this manual or the machine delivery. Additional documentation should be requested.

2 Dismantling

1. Separate and ground the main supply cables, secondary rotor cables and all auxiliary cables from electric power network. Remove possible pipes, hoses, instrument cables and grounding cables.

2. Depending of the extent of the dismantling work remove also top-mounted attachments, hold-down bolts, dowel pins and dismount the coupling half.

Item 3 for air-to-air cooled vertical machines only

3. Place the lifting hooks to the lifting points of the air duct between the outer fan cover and heat exchanger of the machine. Remove the mounting screws and lift the air duct up. Remove also the air duct between the outer fan cover and heat exchanger of the slip ring unit (machines with permanent contact type slip ring unit only).

Items 4-6 for vertical machines only

4. Place the lifting hooks to the lifting points of the heat exchanger (upper cover) of the slip ring unit (permanent contact type slip ring unit only). Remove the mounting screws of the heat exchanger and lift it up. Perform the same procedure for the heat exchanger of the main machine (upper cover).

5. Place the lifting hooks to the lifting points of the machine frame. Remove the mounting screws of the machine and lift it up.

> **Note!** Use a lifting beam to avoid damaging the slip ring unit. See Chapter "Transport and Storage" for lifting instructions.

6. Turn the vertical machine to horizontal position. Use one hoist for lifting and another for tilting.

> **Note!** If it is difficult to remove the motor from its site, partial maintenance may be possible to be done also in vertical attitude. If the bearings are to be changed, the rotor shall be hold up by some special device.

Items 7, 8 and 9 are for air-to-air cooled horizontal machines only.

7. Remove the D-end SPM nipple (machines with antifriction bearings only). Place the lifting hooks to the lifting points of the external fan cover. Remove the mounting screws and lift the cover up.

8. Remove the outer circlip and gently withdraw the fan from the shaft. Remove also the key and the inner circlip.

9. Place the lifting hooks to the lifting points of the air duct (between the heat exchangers of the machine and slip ring unit. Remove the mounting screws and lift the air duct up.

Item 10 for horizontal machines only.

10. Place the lifting hooks to the lifting points of the heat exchanger (upper cover) of the slip ring unit (permanent contact type only). Remove the mounting screws and lift the heat exchanger up. Perform the same procedure for the heat exchanger of the machine (upper cover).
11. Disconnect the connecting copper busbars from the brush rocker and the termination bushing inside the slip ring housing.

Items 12-19 for machines with permanent contact type slip ring unit only.

If the motor is equipped with brush lifting type slip ring unit, follow the dismantling instructions presented in Chapter "Slip Ring Unit with Brush Lifting Device". After that, continue the dismantling work from item 22.

12. Remove the mounting screws of the fan of the slip ring unit and dismantle the fan.
13. Place the lifting hooks to the slip ring housing, open the retaining bolts, and remove the slip ring housing. Removing of the slip ring housing may not be necessary, if only the slip ring assembly has to be changed.
14. Open the spring assemblies of the brush holders and lift the carbon brushes up. Brush holders can also be removed if that is needed.
15. Disconnect the rotor cables from the slip ring bolts.
16. Mount a withdrawal tool to the balancing disk of the slip ring assembly and gently withdraw the slip ring assembly from the shaft.
17. Disconnect and remove auxiliary cables between the machine frame and the slip ring support plate.
18. Remove the two semi-circular shaft sealing plates on the support plate.
19. Place the lifting hooks to the support plate. Open the four distance bolts and remove the support plate.

Items 20-21 for air-to-air cooled vertical machines only.

20. Remove the outer circlip of the external fan and gently withdraw the fan from the shaft. Remove also the key and the inner circlip.
21. Place the lifting hooks to the external fan cover. Remove the mounting screws and lift the cover up.

Now the machine has no heat exchangers (upper covers) or slip ring unit and it is ready for continuing the dismantling work.

Items 22-30 for machines equipped with antifriction bearings.

When dismantling and reassembling the machine, pay attention to the optional bearing insulation between the bearing housing and bearing shield at the N-end (Fig. 1). The purpose of the insulation is to stop possible shaft currents flowing trough the bearings. The grease filling tube is also made of insulated material.

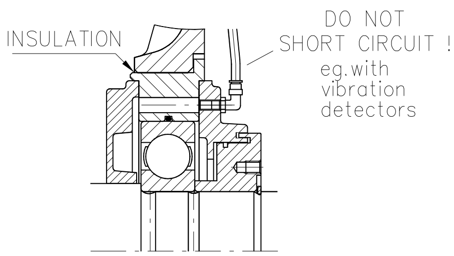


Fig. 1. The insulation of the antifriction bearing.

Dismantle first the axially free bearing (horizontal machines = N-end, vertical machines = D-end. Different bearing constructions are shown in Chapter "Appendices".

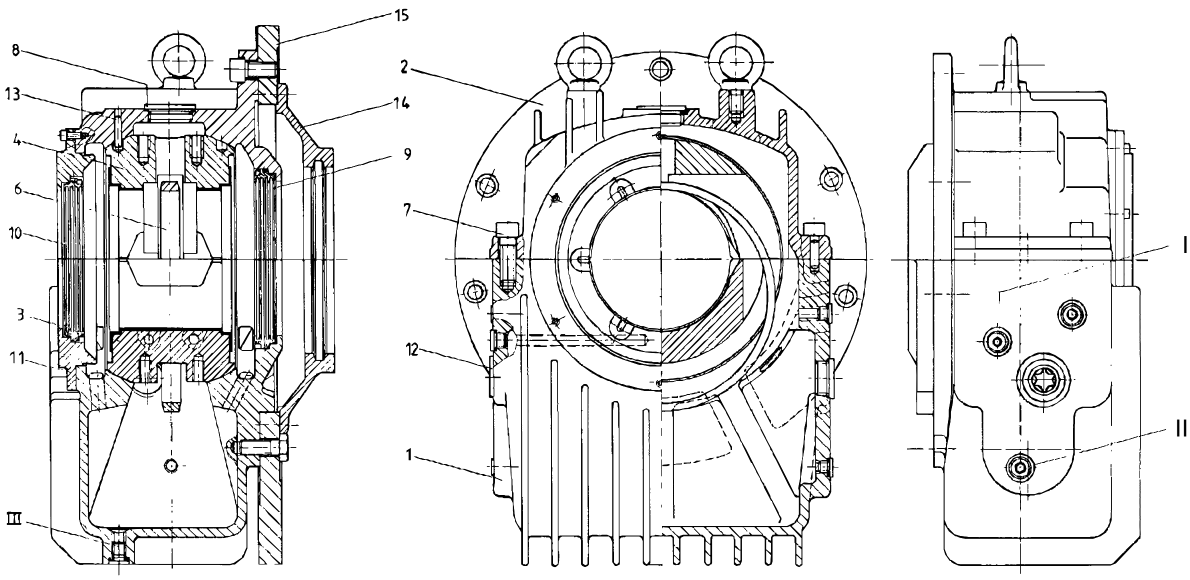
22. Remove the grease filling tube and possible Pt-100, thermocouple or vibration probe of the bearing.
23. Remove the circlip of the grease valve and pull the valve out by using M12 threads.
24. Loosen the outer bearing cover and pull it away.
25. Raise the shaft end by only a few tenths of a mm by using a jack.
26. Remove the end shield (the end shield is drawn out by gently tapping the rim of the shield). Use the threaded holes to pull out the shield.
27. Let down the rotor and remove the jack.
28. Pull out the bearing. Use an adequate bearing withdrawal tool set which will apply pressure only on the inner bearing ring.
29. Remove the springs which preload the bearing (axially free bearings only). Pull away the inner cover.

> **Note!** The bearing must be protected from dust and moisture by wrapping it up in e.g. waxed paper if the bearing is going to be reused. Reusing is not recommended.

Items 30-43 for machines equipped with sleeve bearings (Figure 2 and Chapter "Appendices).

Clean the working place and the bearings thoroughly before dismantling. Dismantle first the D-end bearing and repeat the same procedure for the N-end bearing.

30. Drain off the bearing oil.
31. Disconnect possible oil pipe connections and remove possible Pt-100 or thermocouple and vibration probe of the bearing.
32. Remove the seal carrier (11).
33. Remove the fastening screws of the machine seal (14) (bearing size EFZL_ 9 only).
34. Unscrew the flange bolts of the top part of the housing (2) on the machine end shield (15) and the joint bolts (7) on the bottom part (1).
35. Raise the top part of the housing carefully (just enough to open the housing joint evenly). Swing the top part out of the machine end shield and lift it off.
36. Mark the assembly position of the upper bearing shell (4) and take it off carefully.
37. Unscrew the bolts of the oil ring (6) and handle the two halves carefully in a way not to affect their true geometric shape.
38. Open the garter springs of the shaft seals (9 and 10) by turning left on the lock and remove the shaft seals.
39. Raise the shaft end by only a few tenths of a mm just enough to relieve the lower bearing shell (3). Use a jack.
40. Swing the lower bearing shell (3) up and lift it up.
41. Remove the housing bottom part (1). After that remove the end shield (15) with the machine seal (14). Use the threaded holes to pull out the shield (bearing sizes EFZL_ 11 and EFZL_ 14 only).
42. Remove the end shield (15) with the housing bottom part (1) and the machine seal (14). Use the threaded holes to pull out the shield (bearing size EFZL_ 9 only).
43. Let down the rotor and remove the jack.



1	Housing bottom part	7	Joint bolt	12	Oil level gauge	I	for temperature control
2	Housing top part	8	Oil ring sight glass	13	Retention pin	II	for temperature control in oil sump
3	Lower shell	9	Inboard shaft seal	14	Machine seal		
4	Upper shell	10	Outboard shaft seal	15	Machine shield	III	for oil outlet
6	Loose oil ring	11	Seal carrier	16	Oil outlet		

Fig 2. Sleeve bearing.

Items 44-48 for all AMK machines

44. Remove the circlip of the fan and gently withdraw the fan from the shaft. Remove also the key. Then remove the mounting

screws of the inner air guide and dismantle it.

45. Remove the rotor by using a special supporting tool. Do not allow the rotor to touch the stator.

46. Disconnect the stator connection and all auxiliary cables. Check that the cables can move freely.

47. Turn the frame N-end upwards and attach the lifting eyes and crane to the threaded holes on the stator end ring.

48. Remove the two stator fixing bolts on both sides of the frame and possible other fixing bolts on top of the frame. Lift the stator from the frame.

3 Reassembly

Prior to reassembly, check and verify that all parts are in acceptable condition. Dirtiness must be cleaned and worn out parts replaced.

If a new bearing must be fitted, its type designation must be exactly the same as on the rating plate of the machine.

1. Turn the frame N-end upwards. Move the stator down to the frame with a crane. Tighten the mounting screws. Use suitable locking agent to lock the screws.
2. Turn the frame to horizontal position. Connect the stator connection and all auxiliary cables.
3. Turn the frame to horizontal position. Install the rotor with a special supporting tool. Do not allow the rotor to touch the stator.
4. Attach the air guide.
5. Heat up the hub of the fan to max 100°C (212°F) and mount the fan with a key on the shaft. A thin layer of suitable lubrication and assembly paste is needed between the hub and shaft.

Items 6-17 for antifriction bearings only.

6. Place the inner bearing covers in position. Axially free bearings are equipped with springs, which must be attached at this point. Fill the bearing covers fully with new appropriate grease (see Chapter “Maintenance” for appropriate grease types).
7. Heat up the bearings to 110°C (221°F) by using an induction heater.
8. Lubricate the shaft surface with a thin layer of suitable lubrication and assembly paste and fit the bearings on the shaft. Fill them fully with new appropriate grease. Remember the absolute cleanness with all bearing parts and grease. Reusing of an old bearing is not recommended.
9. Lubricate the bearing housing bore with a thin layer of suitable lubrication and assembly paste and lift the bearing shield of the axially fixed end on its position. Tighten the screws evenly opposite side.
10. Fit and attach the outer bearing cover. Use suitable sealing agent on the mating surfaces. Fill the cover fully with new appropriate grease. Tighten the screws.
11. Install the grease valve.
12. Attach the circlip.
13. Place a new O-ring onto the bearing housing bore of the end shield (axially free end). A thin layer of suitable lubrication and assembly paste is needed between the housing and the bearing. If the machine is equipped with insulated end shield, measure and ensure the insulation resistance over the bearing housing and the end shield.
14. Lift the bearing shield of the axially free end on its position and tighten the screws evenly opposite side. Use suitable sealing agent on the mating surfaces.
15. Fit and attach the outer bearing cover. Fill the cover fully with new appropriate grease. Tighten the screws.
16. Install the grease valve and attach the circlip.

Items 17-26 for D-end sleeve bearing only.

17. Attach the bottom part of the bearing housing to the end shield.
18. Place the machinery seal, lubrication ring and the springs holding shaft seals hanging on the shaft in appropriate places.
19. Lift the rotor as much as the air gap allows.
20. Lift the bearing shield on its position and tighten the screws evenly opposite side.
21. Put the bottom bearing shell on its place, let the shaft down on the bearing and install the shaft seals.
22. Put the upper bearing shell on its place.

23. Apply luting agent on the bottom part of the bearing housing (Figure 3).

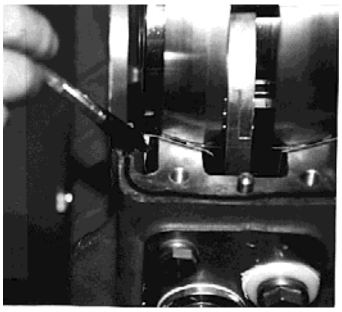


Fig. 3. Applying luting agent.

24. Attach the upper part of the bearing housing.

25. Attach the dust seal.

26. Fill the bearing with appropriate oil to correct level (to the middle of oil sight glass).

Item 27 for the N-end sleeve bearing only.

27. Perform the same procedures as described in items 17 to 26 for the D-end bearing. Notice that the N-end bearing is insulated (the inside spherical housing surfaces are lined with nonconducting PTFE housing).

Items 28-39 for reassembly of the slip ring unit.

If the machine is equipped with brush lifting type slip ring unit, follow the instructions presented in Chapter “Manual for Slip Ring Unit with Brush Lifting Device. After the applicable items continue the reassebly from item 41.

Before the slip ring unit is reassembled, the slip ring housing, heat-exchanger, slip ring gear, brush rocker and other parts must be cleaned. If the slip ring unit is equipped with internal cooling air circuit filter, the filter has to be cleaned or changed if needed. Follow the cleaning instructions presented in Chapters "Maintenance” and “Slip Ring Unit with Brush Lifting Device”.

> **Note!** If gaskets of the slip ring housing have to be changed or lubricated, do not use any silicone based material e.g. silicone rubber, silicone plastic or silicone grease.

28. Mount the four distance bolts and the support plate. With air-to-air cooled vertical machines the external fan cover is mounted before the support plate. Then the hub of the external fan is heated to max 100°C (212°F) and the fan is mounted with the key on the shaft. A thin layer of suitable lubrication and assembly paste is needed between the hub and shaft.

29. Attach the two semi-circular shaft sealing plates on the support plate.

30. Connect auxiliary cables between the machine frame and the support plate.

31. Clean the shaft end at N-end. Polish it if the surface is not smooth. Lubricate it with a thin layer of suitable lubrication and assembly paste. The run-out at the shaft end should be < 0.02 mm.

32. Check the condition of the slip ring and hub hole surfaces. Possible roughness must be machined and polished. If the condition is acceptable, heat the slip ring assembly in oven until the temperature has reached +130° C (+265° F).

> **Note!** Heating the slip ring assembly by other means is not permitted, as it will destroy the insulation.

33. Mount the slip ring assembly. The outer end of slip ring hub should be in line with the end face of the shaft. Allow the slip ring assembly to cool down.

34. Connect the rotor cables to the slip ring bolts. If necessary bend the cables gently while heating them with warm air.

35. Place the carbon brushes down to the brush holders and close the spring assemblies. If the brush holders have been removed, adjust them to 2 mm distance to the slip ring surface. Check that all brushes are similar, in acceptable condition (check the wear limit) and can move freely inside the brush holders.

36. Mount the slip ring housing.

37. Connect the connecting copper busbars to the brush rocker and to the termination bushing.

38. Mount the slip ring unit fan.

39. Connect the electrical connections of the slip ring housing.

Item 40 for horizontal machines only.

40. Change the seals of the heat exchangers (upper covers) and mount them.

Items 41-45 for air-to-air cooled horizontal machines only.

41. Clean the shaft surface and lubricate it with a layer of suitable lubrication and assembly paste. Attach the inner circlip.

42. Heat up the hub of the fan to max 100°C (212°F) and mount the fan with a key on the shaft. Attach the outer circlip.

43. Mount the external fan cover.

44. Mount the D-end SPM nipple (machines with antifriction bearings only).

45. Mount the air duct (between the heat exchanger of the machine and slip ring unit.

Items 46-48 for vertical machines only.

46. Place the lifting hooks to lifting points of the frame and flange. Turn the machine to vertical position by using one hoist for lifting and one for tilting.

47. Put the machine on the foundation and attach the mounting bolts.

48. Change the seals of the heat exchangers (upper covers) and mount them.

Item 49 for air-to-air cooled vertical machines only.

49. Mount the air duct between the external fan cover and heat-exchanger of the machine. If the machine is equipped with an other air duct between the external fan cover and heat exchanger of the slip ring unit, mount the duct.

Items 50-53 for all AMK machines.

50. Place the auxiliary devices in their positions and connect their cables.

51. Connect all pipes, hoses, instrument cables and/or grounding cables between heat exchangers (upper covers) and machine frame.

52. Lubricate the bearings with appropriate lubricants as presented in Chapter “Maintenance”.

53. Follow the instructions presented in Chapters “Installation and Alignment”, “Mechanical and Electrical Connections” and “Commissioning and Start-up”

SCHEDULE FOR REGULAR CHECKINGS	PERIOD			
	Daily	**Monthly**	**Yearly**	**During complete overhaul**
Power	X			
Current	X			
P.F.	X			
Excitation current	X			
Winding temperatures	X			
Bearing temperatures	X			
Cooling air temperatures	X			
Oil pressures	X			
Bearing vibration		X		
Heat exchangers		X		
Contamination		X		
Cleanliness of inner parts of the machine			X	
Cleanliness of diodes and diode bridges			X	
Condition and support of windings, lockings			X	
Possible shifting of the slot wedges			X	
Condition of the winding insulation and finishing varnish			X	
Possible shifting or loosening of the field windings			X	
Insulating resistances of the windings			X	
Condition of the fan			X	
Lockings in connection with the rotating parts			X	
Painting and protection against corrosion			X	
Checking the seals preventing the ingress of dirt			X	
Checking the performances of control and regulation equipment as well as protective relays			X	
Checking of rust caused by vibration on stator core				X
Checking the condition of the rotor winding supports				X
Checking the solderings and possible broken bars of the rotor damper winding				X
Bearings and bearing seals				X

Chapter 9 – Slip Ring Unit with Brush Lifting Device

Chapter 9 – Slip Ring Unit with Brush Lifting Device

1 General

1.1 Rated values of the slip ring gear

This slip ring gear is used for motors having the rated rotor current I2 < 1000 A and the rated rotor voltage U2 < 2500 V.

1.2 Purpose

The purpose of the slip ring gear with brush lifting and short circuiting device is to allow the motor to start with an adjustable and controllable amount of current and/or torque and run the motor with the rotor winding short circuited without brush wear.

1.3 The main parts of the slip ring gear

The slip ring gear consists of the following main parts: actuating motor (2, Appendix 11 in Chapter “Appendices”), lifting mechanism (6, A11), brush rocker with collecting rings (10, A11), slip ring assembly (9, A11), and housing (1-8, A10). The actuating motor is situated outside of the slip ring housing, and it manoeuvres the brush lifting and short circuiting mechanism. The brush rocker carries the brush holders and brushes. Normally the actuator motor is automatically switched on and off synchronized with the starter functions.

The slip ring assembly is shrunk on to the shaft, and rotates with the rotor. The slip rings are connected to the rotor winding with cables going through a hole in the shaft, thus enabling connection between the rotor circuit and the starter resistors.

1.4 Operating functions of the slip ring gear

1.4.1 Starting position

The motor shall always be started with the brushes (3, A15) down, touching the slip rings (6-8, A12), and the short circuit ring (1, A12) in open position (pos1, A17).

1.4.2 Change from starting position to running position

When the motor during start has reached its running speed, the actuator motor (2, A11) is powered getting the short circuiting and brush lifting gear in function. First the lifting mechanism (6, A11) will close the short circuit ring (1, A12) to the slip ring assembly (9, A11) short circuiting the slip rings (6-8, A12), and the rotor winding and then lift the brushes (3, A15) away from the slip rings.

First the fork (15, A13) moves a few mm towards the D-end of the motor, then the fork changes direction of its movement (pos2, A17), moving towards the slip ring assembly, thus moving the short circuit ring (1, A12) to close (pos3, A17) the short circuiting contact parts (3, A12) and (5, A12). After closing the contacts between the short circuit ring and slip ring assembly (9, A11) the brush lifting mechanism lifts by the lever (8, A13) and the wire (14, A13) the brushes (3, A15) away from the slip rings. After that the fork returns (pos4, A17) a few mm towards the D-end of the motor to give 2-5 mm clearance to the bearings (detail 1, A17) on the ends of the fork. Then the actuator motor is normally automatically switched off and the movements of the lifting mechanism are stopped (pos5, A17) to the running position.

Note! In the running position the starter resistors shall be short circuited, and the short circuiting shall be happened before the brushes are lifted up from the slip rings.

Note! When the starter resistors are short circuited, the voltage drop in the starter and in the cables between the slip ring gear and starter shall not exceed 5 volts at the rated rotor current I2 of the motor. This means that, if the cables are dimensioned for a current density of 1 ... 1.5 A/mm², the distance between the motor and the starter should be < 20 m.

1.4.3 Running position

In running position the bearings (3, A17) on the ends of the fork will be situated in the groove of the short circuit ring (2, A17) in such a way that the bearings will have a minimum clearance of 2 mm to the short circuit ring (detail 1, A17).

1.4.4 Stopping the motor

When the motor has to be stopped, the lifting mechanism will in reverse order move the brushes

(3, A15) down, and then the short circuit ring (1, A12) back to starting position (pos1, A17).

Note! Starter functions shall always be syncronized with the slip ring gear functions according to the starter instructions.

2 Inspection of the motor upon delivery

The slip ring housing and the actuator motor housing have to be checked for visual damages. Any detected damage should be photographed, and reported to the supplier of the motor.

3 Commissioning

3.1 Connecting the actuating motor

Before starting the AMK motor, the actuating motor (2, A11) has to be electrically connected and its adjustments checked. When the cables are connected according to the manual, the function of the actuator can and shall be checked without starting the AMK motor.

4 Starting of the motor

Note! Failure in starting the motor without checking the adjustments of the components of the complete slip ring gear can result in serious damage! Also connections to the starter and functions with it shall be checked!

Before the AMK motor is started the first time, the following items shall be thoroughly checked.

4.1 Lifting mechanism

The lifting mechanism (6, A11) shall be in the starting position, i.e., the short circuit ring (1, A12) in open position, and the brushes (3, A15) down.

4.2 Brushes

All nine brushes (3, A15) shall be in starting position, i.e., down and in good contact with the slip rings (6-8, A12).

Check during the first starts, that the brushes are not sparking. If sparking is found, reasons for it shall be checked and clarified before continuing the use.

4.3 Short circuit ring

The short circuit ring (1, A12) shall be in open position, i.e., in the position where the contact females (3, A12) of the short circuit ring do not make any contact with the contact pins (5, A12) of the slip ring assembly (9, A11).

4.4 Electric movement limits of the actuating motor

The electric movement limits (6-15, A18), i.e., the adjustments of the limit switches of the actuating motor (2, A11) must be checked so that the lifting mechanism (6, A11) will stop at proper positions.

5 Maintenance in normal use

The slip ring gear and slip ring housing shall be checked at regular service intervals.

5.1 Brushes, brush holders

The brushes (3, A15), (1, A16) will normally wear in use, and shall be replaced before they are worn out. The brushes shall be checked at regular intervals, and must be replaced latest when the wear has reached the wear limit mark (25, A16). When the brushes are replaced the brush rocker must be re-adjusted (see ”Adjusting the brush rocker and brushes”).

It has to be checked also at regular intervals, that the brushes can freely move in the brush holders and that the brush contact surfaces are in good condition without burning marks.

5.2 Contact surfaces of the slip rings

Check at regular intervals, that the contact surfaces of the slip rings are smooth without grooves, burning marks etc. The contact surfaces of the rings shall be clean, any dirt has to be removed. Formation of patina on the contact surfaces is desirable, but often it can be thin on steel rings.

5.3 Contact parts

It shall be checked at regular intervals, that the contact surfaces of the contact pins (3, A12) of the short circuit ring (1, A12) and of the contact females (5, A12) of the slip ring assembly (9, A11) are in good condition without burnings or dirt on the surfaces. Clean or replace, if needed.

5.4 Moveability of the short circuit ring

It shall be checked at regular intervals, that the short circuiting ring can easily move on its sliding surface (hub extension of the slip ring assembly or shaft of the rotor). Sliding surface shall be cleaned from dirt and excessive carbon dust. The sliding surfaces can be greased, when needed, applying a thin film of MoS2 lubricant for example Rocol A.S. Paste or Spray from Rocol Ltd, Leeds England.

5.5 Carbon dust

Carbon dust is electrically very conductive and it can make conductive layers on the insulating surfaces. Carbon dust can also block the brushes into the brush holders. Therefore especially the slip ring assembly (9, A11) and the brush lifting device (6, A11) shall be kept clean. Also no foreign particles or dust may enter the slip ring housing (1-8, A10). Carbon dust may be removed at regular intervals with air jet, and vacuum cleaner; no detergents may be used.

6 Dismantling of the slip ring gear

In order to access the N-end of the AMK motor (1, A11), for example to change the antifriction bearing at the N-end, the slip ring assembly (9, A11), the lifting mechanism (6, A11), the brush rocker (10, A11) and the housing (1-8, A10) have to be removed.

Removal is carried out as follows:

1. Disconnect the AMK motor from the electrical mains supply.

2. Remove the electrical connections of the slip ring housing (6, A10).

3. Disconnect the connecting copper busbars (7, A10) from the brush rocker (10, A11), and the termination bushing (6, A10).

4. Remove the shaft (5, A11) between the actuator motor (2, A11) and the lifting mechanism (6, A11) by opening the locking screw (23, A14) of the lower cardan joint (18, A13) (on some models both pins of the lower cardan joint). Then move the shaft (5, A11) towards the actuator motor, off the joint, to the side of the joint and away from the actuator motor.

5. Open the retaining bolts, and remove the actuator motor (2, A11) and the intermediate flange (4, A2).

6. Open the retaining bolts, and remove the slip ring housing (1-7, A10).

7. Disconnect the wire (8, A11) from the lifting mechanism (6, A11) and the brush rocker unit (10, A11) by detaching the spring (7, A11), and loosening the brush rocker locking screws (20, A16).

8. Remove the lifting mechanism (6, A11) from the support plate (11, A11) by opening two bolts.

9. Lock the brush lifting arms (23, A16) in “brushes up” position, i.e. where the brushes (3, A15) are lifted as far away as possible from the slip rings (6-8, A12).

10. Carefully remove the brush rocker (10, A11) from the support plate (11, A11) by opening three connecting bolts.

11. Place a spring and ball mounting tool on the hub (AMK 400 and 450) or shaft (AMK 500), and carefully push the short circuit ring (1, A12) towards the D-end of the AMK motor.

> **Note!** There are spring (13, A3) tensioned balls (12, A3) underneath the short circuit ring (1, A3). Open carefully.

12. Remove the ball(s) (12, A12) and the spring(s) (13, A12) underneath the short circuit ring (1, A12).

13. Disconnect the rotor cables (11, A12) from the slip ring bolts (9, A12), and bend them carefully while heating them with warm air, as to let them pass through the slip ring hub (15, A12).

14. Mount a withdrawal tool to the balancing disk (16, A12) of the slip ring assembly and gently withdraw the slip ring assembly from the shaft.

15. Remove the short circuit ring (1, A12).

16. Remove the support plate (11, A11) and the four distance bolts (13, A11).

7 Assembling of the slip ring gear

1. Mount the four distance bolts (13, A2) and the support plate (11, A11).

2. Bend the rotor cables (11, A12) gently while heating them with warm air as to let them pass through the slip ring hub (15, A12).

3. Mount the short circuit ring (1, A12) on the rotor.

4. Heat the slip ring assembly (9, A11) in oven until the slip ring assembly has reached +130° C (+265° F).

> **Note!** Heating the slip ring assembly by other means is not permitted, as it will destroy the insulation.

5. Mount the slip ring assembly (9, A11). The outer end of slip ring hub (15, A12) should be in line with the end face of the shaft. Allow the slip ring assembly to cool down.

6. Connect the rotor cables (11, A12) to the slip ring bolts (9, A12). If necessary bend the cables gently while heating them with warm air.

7. Place the spring(s) (13, A12) and ball(s) (12, A12) in appropriate holes. If necessary, use an mounting tool.

8. Place the short circuit ring (1, A12) over the ball(s) (12, A12), and be careful not to move the ring as to let the ball(s) escape. The sliding surfaces shall be greased applying a thin film of MoS2 lubricant for example Rocol A.S. Paste or Spray from Rocol Ltd, Leeds England.

9. Mount the brush rocker (10, A11) after having locked the brushes (3, A15) in the “brushes up” position.

10. Unlock the brush lifting arms (23, A16) and put the brushes into holders.

11. Mount the lifting mechanism (6, A11).

12. Mount the wire (8, A11) to the lifting mechanism and to the brush rocker (10, A11).

13. Mount the intermediate flange (4, A11) and the actuator motor (2, A11).

14. Mount the shaft (5, A11) between the lifting mechanism (6, A11) and the actuator motor (2, A11).

15. Adjust the lifting mechanism (6, A11) (see below).

16. Remove the shaft (5, A11) between the lifting mechanism (6, A11) and the actuator motor (2, A11).

17. Mount the slip ring housing (1-7, A10).

18. Re-mount the shaft (5, A11) between the lifting mechanism (6, A11) and the actuator motor (2, A11).

19. Connect the copper busbars (7, A10) to the brush rocker (10, A11), and to the termination bushing (6, A10).

20. Connect the electrical connections of the slip ring housing (6, A10).

21. Check the adjustment of the lifting mechanism (6, A11), the brushes (3, A15), and the actuator motor (2, A11) (see below).

22. Connect the AMK motor to the electric mains supply.

8 Instructions for adjusting of the brush lifting device

8.1 Initial position of adjusting of the brush lifting device

The brush lifting device (6, A11) shall be in the following position when adjustment is undertaken:

- Locking washers (10, A13) of the shifting claw (12, A13) open.
- Locking nuts/bolts (2, A13) of the control fork (15, A13) open.
- Locking nuts of the brush lifting arms (3 pcs.) (20, A16) loosened.
- Mechanical end limit (5, A13) not tightened, i.e. the screw (9, A13) loose.

- Actuator crank (3, A11) mounted to actuator (2, A11).

8.2 Aligning the fork

- Move the short circuiting ring (1, A12) to it's middle horizontal position (pos. 3, A17) by turning the actuator crank (3, A11).

- Pull the short circuit ring (1, A12) by hand towards the open position, i.e. towards the motor D-end.

Align the fork bearings (1, A13) to the short circuit ring (1, A12) so that both of the bearings are in contact with same side of the short circuit ring.

Lock the fork (15, A13) position by locking the bolts and locking nuts (2, A13).

8.3 Adjusting the short circuit ring and shifting claw position

1. Start by moving the short circuit ring (1, A12) in to the short circuit position (pos4, A17) by turning the actuator crank (3, A11) clockwise (CW).

2. The axial distance between the short circuit ring (2, A17) and the hub insulator (6, A17) in the closest position should be as small as possible, i.e. the ball (5, A17) should be in the groove of short circuit ring (2, A17). Correct the position by turning the screw (11, A13) and locking nut on the shifting claw (12, A13).

3. After the correct position is reached, turn the actuator crank (3, A11) to move the fork (15, A13) back and forth at least two times in order to ensure that the right position is reached also after a few operations.

4. Tighten the nut of the adjusting screw (44, A14), and lock the washers (29 and 45, A14).

5. Note that when the shifting claw (12, A13) is correctly adjusted in the *short circuit* (run) position, the *circuit open* (start) position will automatically be correct.

8.4 Adjusting the brush rocker and the brushes

1. Turn the actuator crank (3, A11) clockwise (CW) until the eccentric (7, A13) has pushed the lever (8, A13) in its outermost position, i.e. the wire (14, A13) and spring (13, A13) are maximally tensioned. This should correspond with position 5 in appendix 17.

2. Adjust the brushes (3, A15) so that there is a 2-3 mm gap between the brushes and the surface of the slip rings (6-8, A12). The adjustment is done by loosening the locking nut (20, A16), lifting or lowering the lifting arm (23, A16) as to move the brushes by means of the brush holder lever (18, A16).

3. Tighten the three locking nuts (20, A16) in order to lock the position of each set of brushes.

4. Turn the actuator crank (3, A11) counter-clockwise (CCW) and ensure that the brushes (3, A15) touch the slip rings (6-8, A12) before the short circuit ring (1, A12) starts to move towards the D-end of the motor.

8.5 Adjusting the mechanical end limit

1. Turn the actuator crank (3, A11) clockwise (CW) until the short circuit ring (1, A12) reaches it's short circuit position (pos4, A17).

2. Turn the actuator crank (3, A11) further CW until the bearing (3, A17) is in the middle of the groove of the short circuit ring (2, A17). In this position (pos5, A17) there should be an approximate 2-5 mm clearance on all sides of the bearings (detail 1, A17).

3. Turn the mechanical end limit (5, A13) so that it will be in a position 1 mm from the end limit bolt (3, A13). Lock the mechanical end limit (5, A13) by tightening the screw (9, A13) thoroughly.

4. Turn the actuator crank (3, A11) counter-clockwise (CCW) until the short-circuit ring (2, A17) reaches it's circuit open position (pos2, A17).

5. Turn the actuator crank (3, A11) further CCW until there is an approximate 1 mm clearance between the mechanical end limit (5, A13) and the end limit bolt (4, A13).

6. There should now be an approximate 2-5 mm clearance on both sides of the bearings (3, A17) towards the short circuit ring (detail 2, A17). If not, re-start from point 1.

9 The actuator motor

9.1 General

The actuator motor (10, A10) (1, A18) is situated outside the slip ring housing, and is mounted on a special intermediate flange (9, A10) (4, A18). The actuator motor is powered by 230 VAC / 50 Hz / 1 phase, which is connected to terminals 2 or 3, depending on the required function. The neutral lead is connected to terminal 1.

There are four micro-switches (6-9, A18) inside the actuator motor, two on each side, thus corresponding to four rotating disks with actuating cams (10-13, A18). The positions of the cams can be changed by finding the screw (14, A18) with the same color as the cam, pushing it with a screw driver, and turning. The cams shall always operate the switches from ”below” the switch.

The cams are used to adjust the rotating of the motor S2 and S3 as well as giving signals S7 and S8 (terminals 4 to 6, and 7 to 9, A9) to the operating system, signal lamps on the control board etc.

9.2 Connecting the actuator motor

1. Open the cover (2, A18) of the actuator motor (1, A18).

2. Connect the neutral lead of 230VAC/ 50 Hz to terminal 1 (A18).

3. Connect live lead of 230VAC/ 50 Hz for closing short circuit ring, and lifting brushes, i.e. moving towards running position, to terminal 3 (A18).

4. Connect live lead of 230VAC/ 50 Hz for opening short circuit ring, and lowering brushes, i.e. moving towards starting position, to terminal 2 (A18).

5. Connect leads to indicate starting position to terminals 4 and 6 (A18).

6. Connect leads to indicate running position to terminals 7 and 9 (A18).

7. Close the cover (2, A18) of the actuator motor (1, A18).

8. Turn the Manual-Remote-Switch (18, A18) in to ”Remote” position.

9.3 Adjusting the actuator motor

1. Open the cover (2, A18) of the actuator motor (1, A18).

2. Turn the actuator crank (5, A18) until the short circuiting ring (1, A12) is in its middle position (pos3, A17).

3. Turn the actuator crank (5, A18) clockwise (CW) until the running position (pos5, A17) is reached. Note that the bearings (3, A17) are moving towards the AMK motor D-end when this position is reached. During the motion observe the cams (10-11, A18) of the electric limit switches S2 and S8 (6-7, A18) to assure that the switches will be activated from ”below”, i.e. when the cams are rotating CW.

4. Adjust the electric limit switch S2 and S8 (6-7, A18) to switch off 1 mm before the mechanical end limit switch (5, A13) reaches its end position. To move the cam (10-11, A18) of the limit switch, push down and turn the screw in corresponding color (14, A18) in the cam in the desired direction. The cam is automatically locked when the pressure on the screw is loosened.

5. Turn the actuator crank (5, A18) counter-clockwise (CCW) until the starting position (pos1, A17) is reached. Note that the bearings (3, A17) are moving away from the AMK motor D-end when this position is reached. During the motion observe the cams (12-13, A18) of the electric limit switches S3 and S7 (8-9, A18) to assure that the switches will be activated from ”below”, i.e. when the cams are rotating CCW.

6. Adjust the electric limit switch S3 and S7 (8-9, A18) to switch off 1 mm before

the mechanical end limit (5, A13) reaches its end position. To move the cam (12-13, A18) of the limit switch, push down and turn the screw in corresponding color (14, A18) in the cam in the desired direction. The cam is automatically locked when the pressure on the screw is loosened.

7. Remove the crank (5, A18).

8. Connect 230VAC/ 50Hz to terminals 1 and 3.

9. Check that the function is towards running position (short circuit ring closing, brushes moving up) by pushing the lower actuator drive button (15, A18). Check that the actuating motor will stop properly.

10. Remove 230VAC/ 50Hz from terminals 1 and 3, and connect 230VAC/ 50Hz to terminals 1 and 2.

Check that the direction of rotation is towards starting position (brushes moving down, short circuit ring opening) by pushing the upper actuator drive button (17, A18). Check that the actuating motor will stop properly.

11. Connect terminals 1-3 according to the chapter “Connecting the Actuator Motor”.

12. Check the electrical connections of the actuator motor, and switch on the electricity.

13. Close the cover (2, A18) of the actuator motor (1, A18).

14. Turn the Manual-Remote-Switch (18, A18) in to ”Remote” position.

10 Spare parts

The following components can be obtained from the manufacturer as spare parts:

- Actuating motor (2-3, A11)
- Lifting Mechanism (6, A11)
- Slip Ring Assembly (9, A11)
- Set of Slip Ring Short Circuiting Parts (2-5, 17, A12)
- Brush Rocker complete, including Brush Holders, and Brushes (1, 3-5, A15)
- Set of 9 Brushes (1, A16)

When ordering spare parts the following additional information has to be submitted:

Motor type and serial number. For instance: AMK 400L4L BALFT, No. 4532123

11 Appendices

Appendix 10 – Housing Details

Appendix 11 – Slip Ring Gear

Appendix 12 – Slip Ring Assembly

Appendix 13 – Brush Lifting Mechanism

Appendix 14 – Brush Lifting Mechanism, Parts

Appendix 15 – Brush Rocker

Appendix 16 – Brush Bolt

Appendix 17 – Theory of Operation

Appendix 18 – Electrical Connections

Chapter 10 – Checklists

Unpacking and Damages — Checklist 1

Customer	
Machine type	Machine serial no.

Arrival date of the machine	Signature of the consignee

Damage(s): ☐ Machine ☐ Accessories ☐ Package ☐ Other...	Action(s) taken in response to damage(s): ☐ Photographed ☐ Registered ☐ Reported to supplier ☐ Reported to insurance company

Dispatched by: ☐ Airfreight ☐ Railway ☐ Lorry/Truck ☐ Post/Mail ☐ Shipped by the m/s .... ☐ Other...	To carrier

Missing parts / damages found during customer inspection:
After unpacking, store spare parts and installation tools for future use.

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Storage — Checklist 2

Customer	
Machine type	Machine serial no.

Storage period	Person responsible for storage

Storage:	☐ Outdoors	☐ Indoors	
☐ In packing case	☐ Protected by waterproof cover	☐ Warm	☐ Cool

Measures taken during storage:

☐ Case is provided with ventilation openigs	☐ External heating is used	☐ Space heaters are used
☐ Rotor is turned 10 revolutions every two months (antifriction bearings only)	☐ Anti-corrosive coating is checked every 3 months	☐ Absorbing material is used
☐ The inside of sleeve bearing is treated with anti-corrosive oil	☐ Painted surfaces are checked every 3 months	☐ Climate is non-corrosive
☐ Bearing locking is checked	☐ Storage place is vibration-free	
☐ Brushes are lifted up (machine type AMK)		

In case the standstill period is longer than ½ year:
- Check and repeat the oil treatment for sleeve bearings.

In case the standstill period is longer than 2 years:
- Dismantle the sleeve bearing and treat the bearing parts with anti-corrosive oil separately.

Comments:

Protective measures must be taken before operating the machine if it is stored for a long period.

The customer is responsible for the storage and the required protective measures.

The machine must be stored on a level surface in a vibration-free area. If storage is outdoors, the machine must be protected against environmental effects.

If long-time storage under humid conditions is anticipated, connection of space heaters, efficient coverage, and other protective measures must be arranged.

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Installation and Alignment

Checklist 3 **(1/2)**

Customer	
Machine type	Machine serial no.

Measures:

- ☐ Foundation according to drawing...
- ☐ Alignment checked according to instructions.
- ☐ Foundation bolts are tightened with torque wrench.
- ☐ Assembly of coupling half checked.
- ☐ Bearings filled with lubricant - type ....
- ☐ Bearings filled with lubricant - quantity ....
- ☐ Assembly of oil and coolant pipes checked, flanges tightened.
- ☐ Cooling water test run. Check for leakage. Possible leakages are repaired.
- ☐ Stator terminal box mounted correctly.
- ☐ Rotor rotates without scrapings/sound (transport locking device dismantled).

Comments:

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Installation and Alignment — Checklist 3 (2/2)

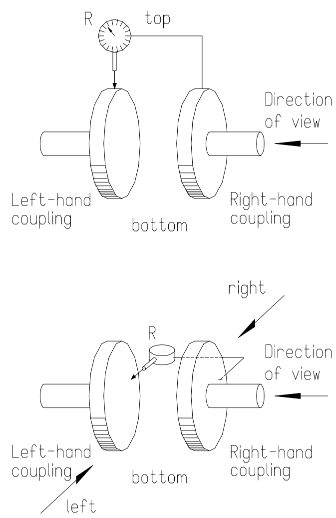
Customer	
Machine type	Machine serial no.

Radial misalignment

a_1, b_1, c_1 and d_1 are readings from the dial indicator "R" at the points a = top, b = bottom, c = right, d = left (4 turns, each of 90° angle). The readings are entered in the formula to obtain the values of radial misalignment (table 1).

Table 1

Measuring points	1st measurement	2nd measurement	Example	
Vertical				
Top	a_1	a_2	25	28
Bottom	b_1	b_2	31	28
Difference	a_1-b_1	a_2-b_2	-6	0
Vertical misalignment	$\frac{a_1-b_1}{2}$	$\frac{a_2-b_2}{2}$	-3	0
+ Left-hand coupling is higher than the right-hand one			Left hand coupling	
- Left-hand coupling is lower than the right-hand one			raised by 0,03 mm.	
Horizontal				
Right	c_1	c_2	38	28
Left	d_1	d_2	18	28
Difference	c_1-d_1	c_2-d_2	20	0
Vertical misalignment	$\frac{c_1-d_1}{2}$	$\frac{c_2-d_2}{2}$	10	0
+ Left-hand coupling displaced to right of right-hand coupling			Left hand coupling	
- Left-hand coupling displaced to left of right-hand coupling			moved to left by 0.1 mm.	
Check for measuring error	$\frac{a_1+b_1}{c_1+d_1} = 1 = \frac{a_2+b_2}{c_2+d_2}$		$\frac{25+31}{38+18} = 1 = \frac{28+28}{28+28}$	



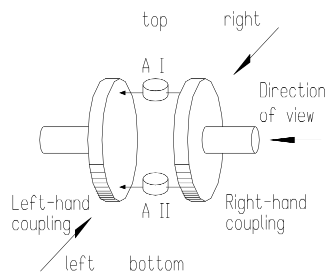
Schematic for table 1

Axial gap and misalignment

The axial gap is determined by taking readings from the two dial indicators AI and AII, whereby the first reading from the top indicator AI is designated by e_1 and that from the bottom indicator AII by h_1. The values for vertical and horizontal misalignment can be determined as shown in table 2; axial displacement (in example 0.2 mm) during the measurement does not effect the results. Use a feeler gauge in case the gap is too small to use a dial gauge.

Table 2

Measuring points	Dial AI	Dial AII	Example	
Vertical gap				
Top	e_1	g_1	50	42
Bottom	f_1	h_1	62	50
Gap	$\frac{(f_1-e_1)-(g_1-h_1)}{2}$		$\frac{(62-50)-(42-50)}{2}$	
+ The gap is greater at the top			The gap is greater by	
- The gap is greater at the bottom			0.1 mm at the top.	
Horizontal gap				
Left	i_1	l_1	40	36
Right	k_1	m_1	48	40
Gap	$\frac{(k_1-i_1)-(l_1-m_1)}{2}$		$\frac{(48-40)-(36-40)}{2}$	
+ The gap is greater at the left			The gap is greater by	
- The gap is greater at the right			0.06 mm at the left.	



Schematic for table 2

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Mechanical and Electrical Connections — Checklist 4 (1/2)

Customer	
Machine type	Machine serial no.

Safety:

☐ **The incoming cables are separated from the electric power network.**

☐ **The cables are grounded.**

Electrical data:

Machine	Electric power network
Voltage..V/VAC	Voltage.............………......................V/VAC
Frequency.......................................Hz	Frequency............………..................Hz
☐ Space heater for machine: .....…......V/VAC, ...….......W ☐ External blower motor: ....……......V/VAC, ...W/HP	☐ *) Space heater for slip ring unit: .....……....V/VAC, ...…....W ☐ *) Brush lifting device ☐ ☐ motor………………V/VAC 1 or 3 phase *) Machine type AMK.

Insulation test: (See chapter: Winding Maintenance for Electrical Machines.)

☐ Stator winding meggered with............. V/VDC, Winding temperature.........…...........°C/°F
☐ Insulation value (after 1 min)......... ..... MΩ, R (40°C/104°F) = ...….. MΩ
☐ Insulation value (after 10 min)............. MΩ, R (40°C/104°F) = ...…...….... MΩ

Main protection settings:

Overcurrent level	Overload level ....
Differential protection level	Ground fault level ....
Negative sequence level	Acceleration time ....
Other protection level(s)	

The supply network is provided with:
Under voltage protection, set at...
Current transformers, ratio..
Voltage transformers, ratio...

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Mechanical and Electrical Connections

Checklist 4 (2/2)

Monitoring equipment		
<u>Temperature monitoring</u>	Alarm (°C/°F)	Trip (°C/°F)
In stator winding		
In bearing		
In..		

<u>Flow or pressure monitoring</u>: (m^3/s or Pa) (ft^3/s or psi)	Alarm	Trip
Lubricating oil	min	
Lubricating oil	max	
Cooling water (machine type AM_)		
Filter guard (machine type AM_)		
Vibration monitoring:		
Comments:		

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Test Run

Checklist 5

Customer	
Machine type	Machine serial no.

Date	Name of supervisor

Connections:

☐ The auxiliary devices have been checked.
☐ The rheostats are connected and the slip ring unit is checked (machine type AMK).
☐ All connections are checked and supply cables earthing is removed.

First start

Direction of rotation:	☐ clockwise	☐ counter-clockwise (as seen from drive-end)
Noise:	☐ normal	☐ abnormal

Second start (to full speed)

Run:	☐ normal	☐ abnormal
Noise:	☐ normal	☐ abnormal
Vibration:	☐ normal	☐ abnormal
Sparking:	☐ normal	☐ abnormal
☐ Run OK	☐ operation stops (why ?)...	

....

Time or Date	Bearing temp.		Winding temperature			Stator		Vibr. (mm/s, µm) (in/sec,mil)		Load (W) (HP)
	D-end (°C/°F)	N-end (°C/°F)	U / T1 (°C/°F)	V / T2 (°C/°F)	W /T3 (°C/°F)	Curr. (A)	Power factor	D-end	N-end	

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ABB

Inspection

Checklist 6

Customer	
Machine type	Machine serial no.

Number of starts during week .... Operating hours during week ....

Comments:

Loggings of operational data and remarks should be kept for reference during maintenance work, trouble shooting and repairs. Copies of loggings are not to be sent to ABB.

Year............. , Week.............		Mon	Tues	Wed	Thurs	Fri	Sat	Sun
Point of inspection	Date							
Load power	(W/HP)							
Load current	(A)							
Fault indication	(Yes/No)							
Bearing temperature DE	(°C/°F)							
Bearing temperature NDE	(°C/°F)							
Oil level	(Normal/Abnormal)							
Oil leakage	(Yes/No)							
Winding temperature U/T1	(°C/°F)							
Winding temperature V/T2	(°C/°F)							
Winding temperature W/T3	(°C/°F)							
Coolant flow	(m^3/h/Gpm)							
Water leakage (mach.type AM_)	(Yes/No)							
Vibration level	(Normal/Abnormal)							
Noise	(Normal/Abnormal)							
Slip ring sparking (Machine type AMK.)	(Normal/Abnormal)							

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Maintenance **Checklist 7**

Customer	
Machine type	Machine serial no.

Maintenance interval...........h, Operating hours ...., Number of starts.....................

<u>Bearings</u>:
- ☐ Lubricant change — Lubricant type................................ Quantity..
- ☐ Oil filter change — Oil filter type...................................
- ☐ Flanges and pipes checked

Comments:

<u>Cooling</u>:
- ☐ Flanges and pipes checked — ☐ Cleaned
- ☐ Air filter checked — ☐ Exchanged
- ☐ Air cooler checked — ☐ Cleaned
- ☐ Water cooler fins (machine type AM_) — ☐ Cleaned
- ☐ Cooling ribs are cleaned (machine type HXR).

Comments:

<u>Electr. part</u>:
- ☐ Connection of high-voltage cables checked
- ☐ Connection of control cables checked
- ☐ Space heater checked
- ☐ Machine opened and inspected
- *) ☐ Slip ring unit checked ☐ Carbons checked ☐ Exchanged

*) Machine type AMK.

Comments:

<u>Mech. part</u>:
- ☐ Couplings checked
- ☐ Foundation bolts checked
- ☐ Foundation checked
- ☐ Machine checked in general
- ☐ Machine opened and checked
- ☐ Bearings opened and checked

Comments:

For files

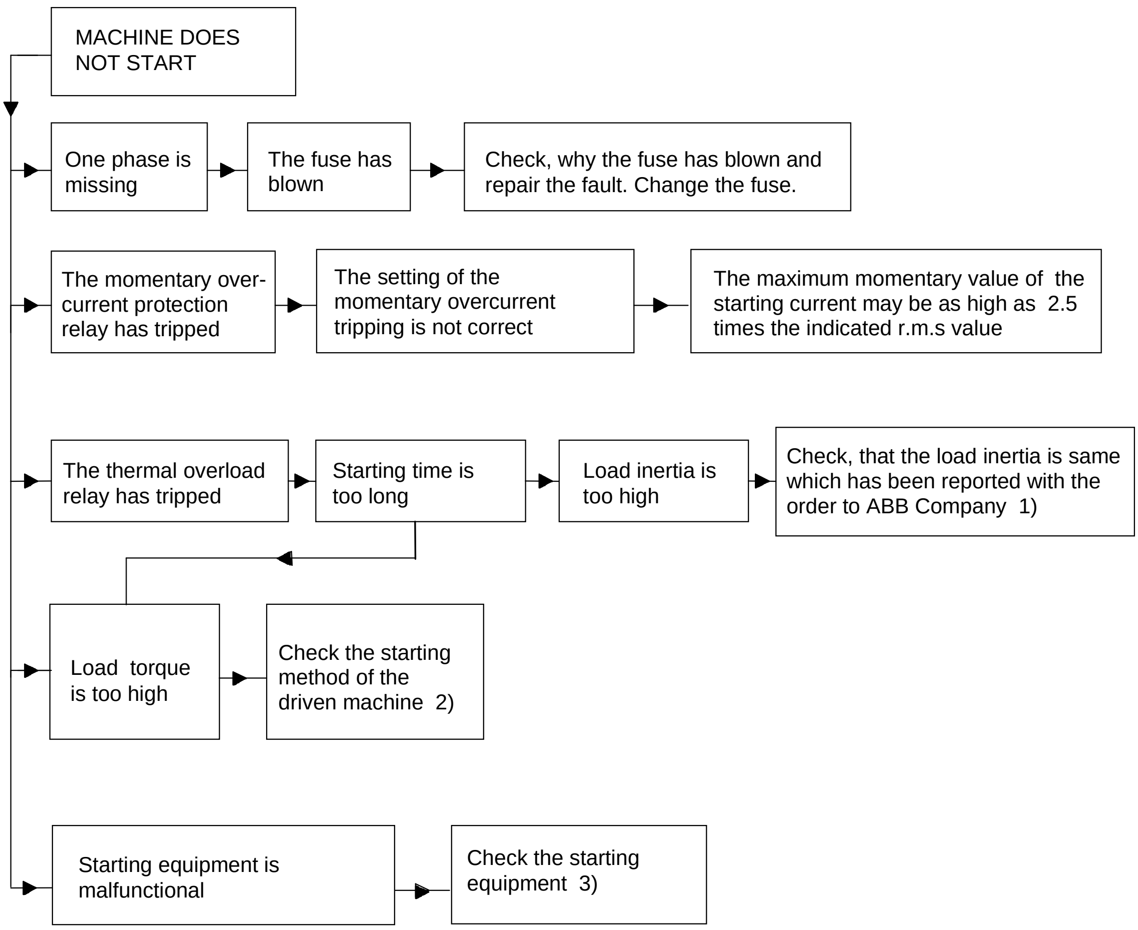
To	From	Date	Page
Issued by		Register no.	Continues on page

Chapter 11 - Trouble Shooting

Starting

Trouble Shooting 1

Customer	
Machine type	Machine serial no



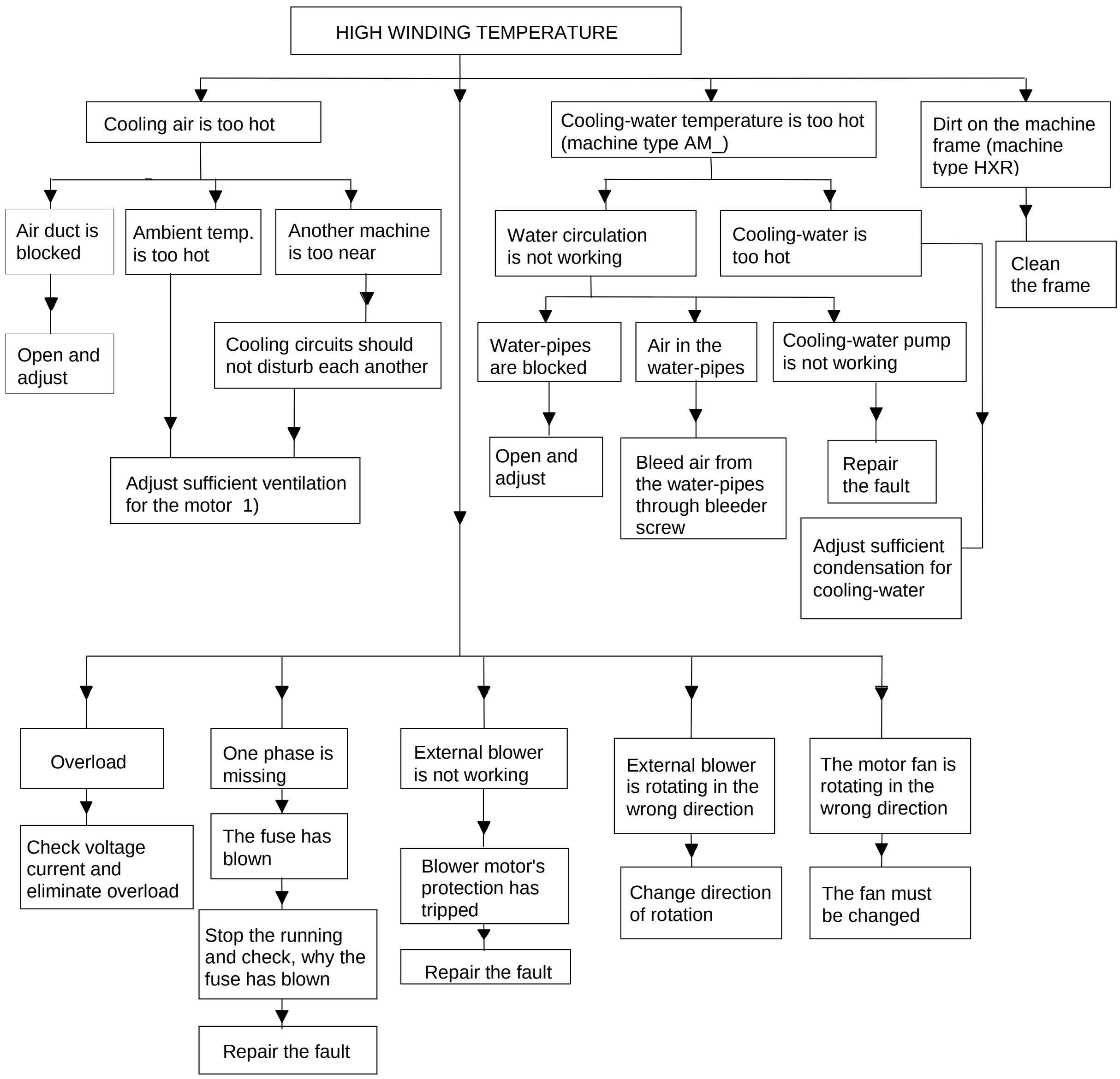
1) If the load inertia is higher than has been reported, please contact your local ABB representative.

2) Driven machines may have different starting methods. Many of them can be started without load. For example compressors and blowers can be started with closed suction vanes. In refiners the pulp feeding can be started after starting the machine. It is possible that the machine does not start loaded, if it has been designed to start without load. In this case the machine can be damaged.

3) The machine manufacturer does not deliver the starting equipment. Please contact your local ABB representative.

Temperature — Trouble Shooting 2

Customer	
Machine type	Machine serial no



1) For example machines can be partitioned off. If the room temperature is too high, the air-conditioning must be improved.

Bearings (Antifriction Bearings) — Trouble Shooting 3 (page 1/4)

Customer	
Machine type	Machine serial no

COMMON SYMPTOMS

A Overheated bearing
B Noisy bearing
C Replacements are too frequent
D Vibration
E Unsatisfactory equipment performance
F Bearing is loose on the shaft
G Shaft is difficult to turn

A	B	C	D	E	F	G	Typical conditions	Reason for condition	Practical solution
•	•	•				•	Inadequate lubrication	Grease or oil is breaking down because it is the wrong type for operating conditions.	Consult lubricant manufacturer to determine proper type of lubricant. Check miscibility if grease or oil has been changed from one type to another.
•	•	•				•	Insufficient lubrication	Insufficient grease in the housing. Low oil level. Lubricant is being lost through the seal.	Fill housing 1/3 to 1/2 with grease. Oil level should be just below the center of the lowest rolling element in the bearing.
•						•	Excessive lubrication	Housing is fully packed with grease or the oil level is too high. This causes excessive lubricant churing, high operating temperature or oil leakage.	Purge bearing until the housing is 1/2 filled with grease. For oil lubricated bearings, reduce the oil level to just below the center of the lowest rolling element.
•	•	•		•		•	Insufficient bearing clearance	Bearing has inadequate internal clearance for conditions where external heat is conducted through the shaft. This causes the inner ring to expand excessively.	Check weather overheated bearing had clearance according to the rating plate of the machine. If so, then change to bearing with increased radial clearance. If not, order according to rating plate. Check with bearing manufacturer if the bearing designation has become illegible.
	•	•	•	•		•	Foreign matter acting as an abrasive.	Dirt, sand, carbon or other contaminants are entering the bearing housing.	Clean the bearing housing. Replace worn seals or improve the seal design to obtain adequate bearing protection.
	•	•	•	•		•	Foreign matter acting as a corrosive.	Water, acids, paints or other corrosives are entering the bearing housing.	Install a protective shield and/or flinger to guard against foreign matter. Improve seals.
	•	•	•	•		•	Foreign matter in bearing housing.	Chips, dirt etc. were not removed from housing before assembling the bearing unit.	Carefully clean and install lubricant.
•	•	•				•	Preloaded bearings	"Two locating bearings" on one shaft. Insufficient axial float in bearing construction caused by excessive shaft expansion.	Improve the possibility of shaft expansion by machining the outer bearing cover.
•	•	•	•	•			Outer ring spins in housing	Unbalanced load.	Rebalance the machine.

Bearings (Antifriction Bearings) — Trouble Shooting 3 (page 2/4)

Customer	
Machine type	Machine serial no

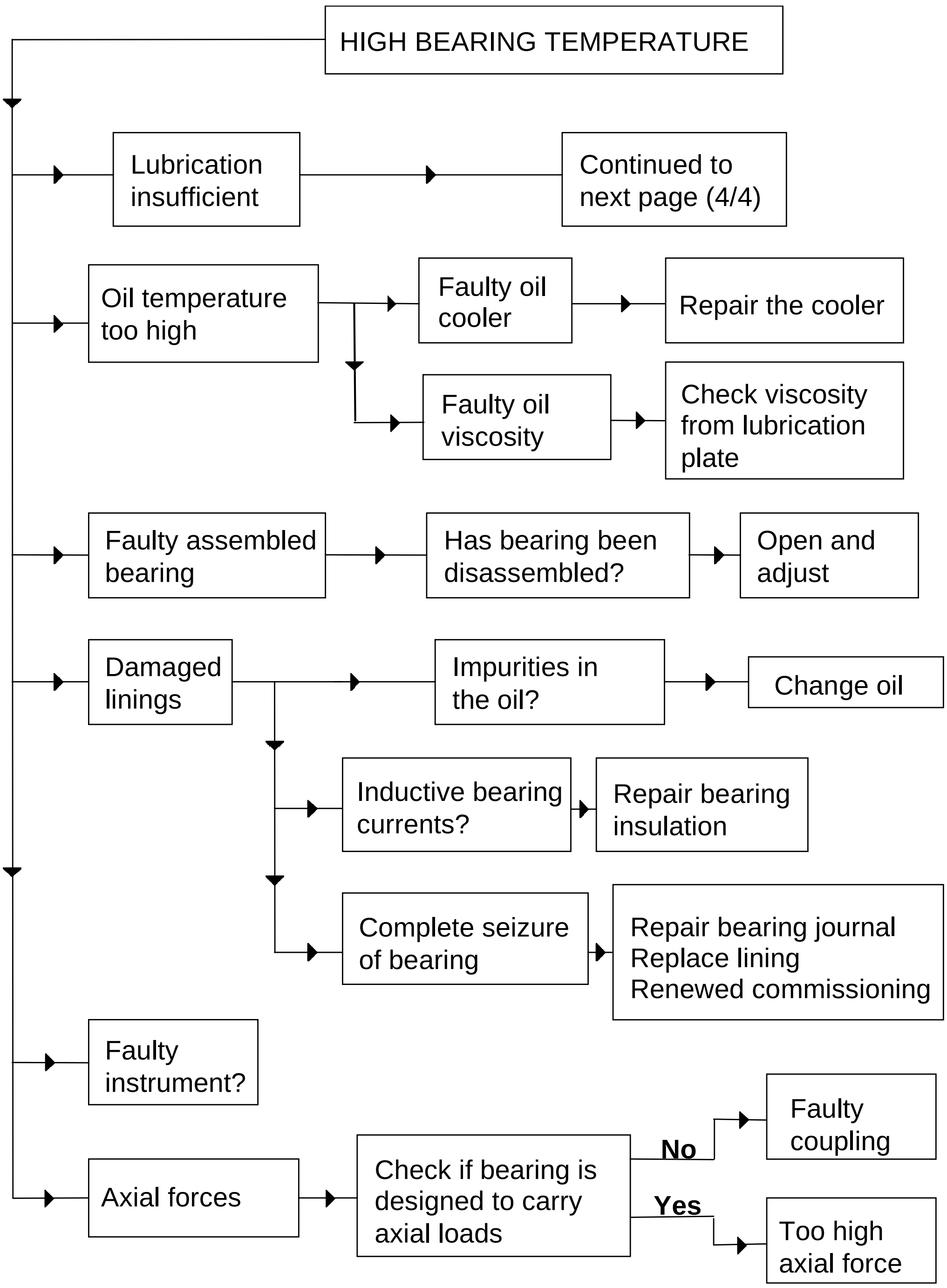
	•		•	•			Noisy bearing	Flat spot on rolling element due to skidding.	Visually check the rolling elements and replace the bearing if a rolling element has flat spot. Make sure that the requisite minimum load is applied to the bearing.
•		•	•	•		•	Linear or/and angular misalignment of shaft.	Incorrect linear or angular alignment of two or more coupled shafts with two or more bearings.	Correct alignment by shimming the electrical machine. Ensure that the shafts are coupled in a straight line. Be sure to use full support shims.
	•	•	•	•			Rolling element is dented.	Incorrect mounting method. Hammer blows on bearing.	Replace the bearing with a new one. Newer hammer any part of a bearing when mounting. Always heat up the bearing before mounting.
	•		•	•			Vibrations	Excessive clearance in the bearing causing vibration.	Use a bearing with recommended internal clearance.
	•		•	•			Vibrations	Equipment is vibrating.	Check the balance of the rotating parts. Rebalance the equipment. Check the stiffness of the foundation. Stiffen the foundation.
	•						Bearing is discolored.	Distortion of the shaft and other bearing assembly components, probably due to heat.	Use a torch to remove a bearing only under extreme circumstances. Avoid high heat concentration at any one point to avoid distortion. Replace discolored bearings.
	•			•			Bearing noisy	Bearing is exposed to vibration while the machine is idle.	Carefully examine the bearing for wear spots corresponding to the spacing of rolling elements. For standby equipment ball bearings are better suited than roller bearings to withstand vibration.

REFERENCE:..

SKF, Maintenance Handbook

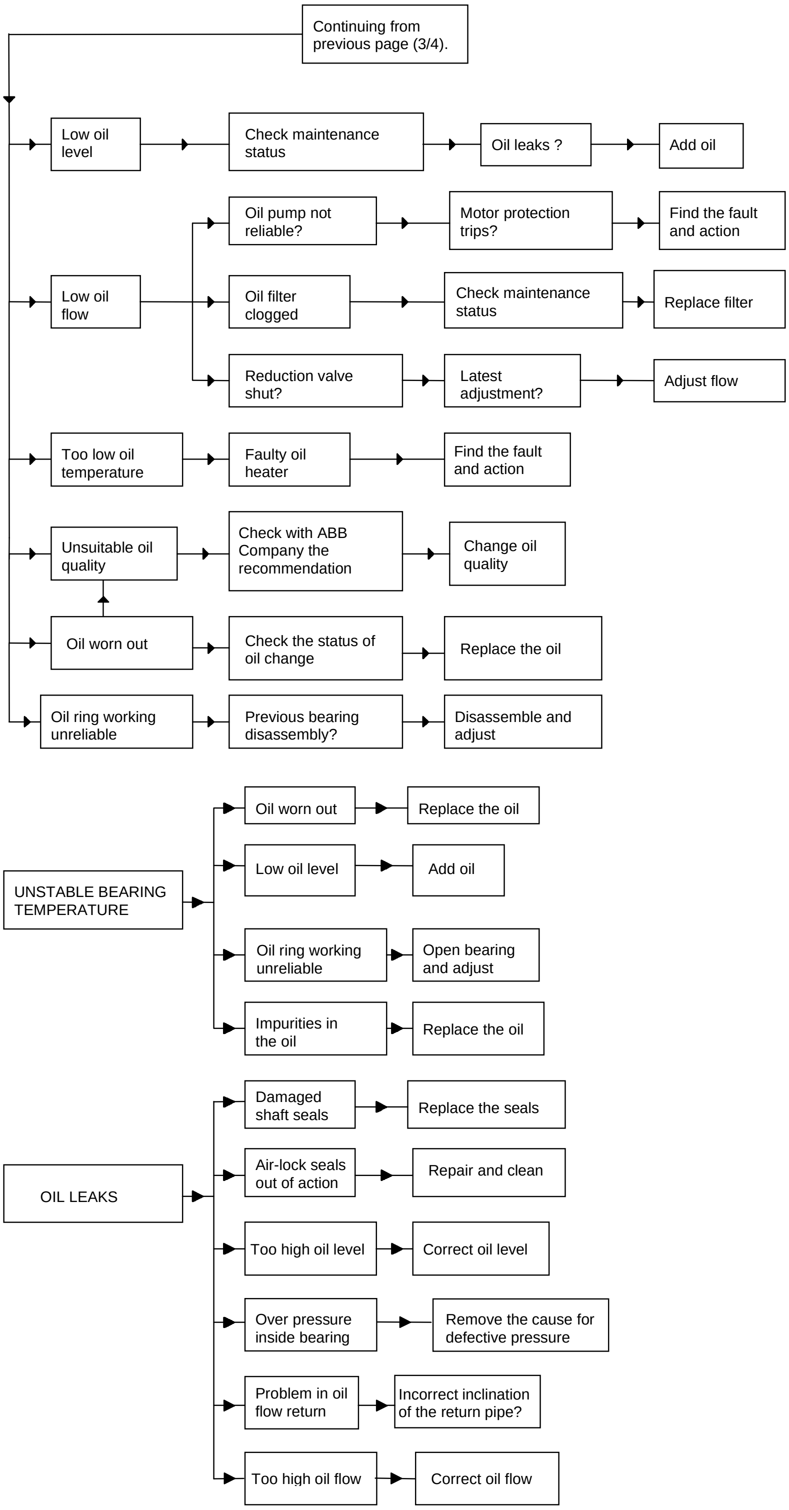
Bearings (Sleeve Bearings) **Trouble Shooting 3 (page 3/4)**

Customer	
Machine type	Machine serial no



Bearings (Sleeve Bearings) — Trouble Shooting 3 (page 4/4)

Customer	
Machine type	Machine serial no



Chapter 12 - Appendices

Appendix 1

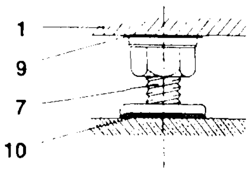
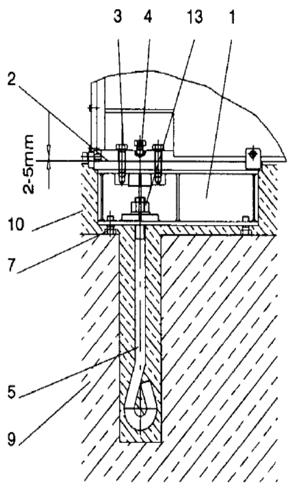
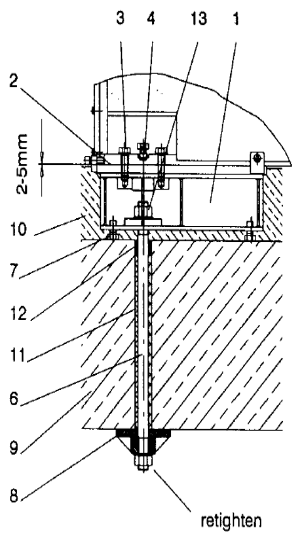
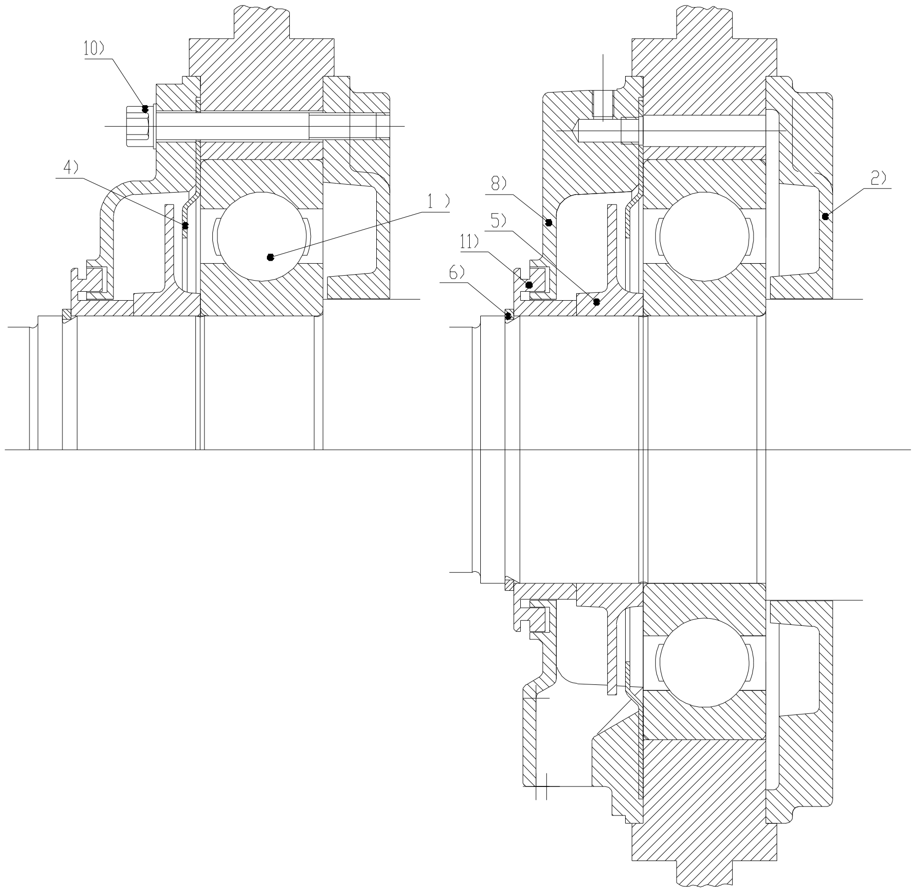
Levelling spindle	**Sole plates/Bedplate with foundation anchor bolts**	**Sole plates/Bedplate with foundation through-bolt**	
 1 Sole plate/bedplate 7 Levelling element 9 Slide plate 10 Synthetic bonding agent			1 Sole plate/bedplate 2 Shims 3 Fastening bolt 4 Dowel pin 5 Foundation anchor bolt 6 Foundation through-bolt 7 Levelling spindle 8 Anchor plate 9 Concrete foundation 10 Grouting 11 Synthetic filling comp. 12 Elastic filling comp. 13 Fastening nut

Fig. 1 Fig. 2 Fig. 3

Appendix 2

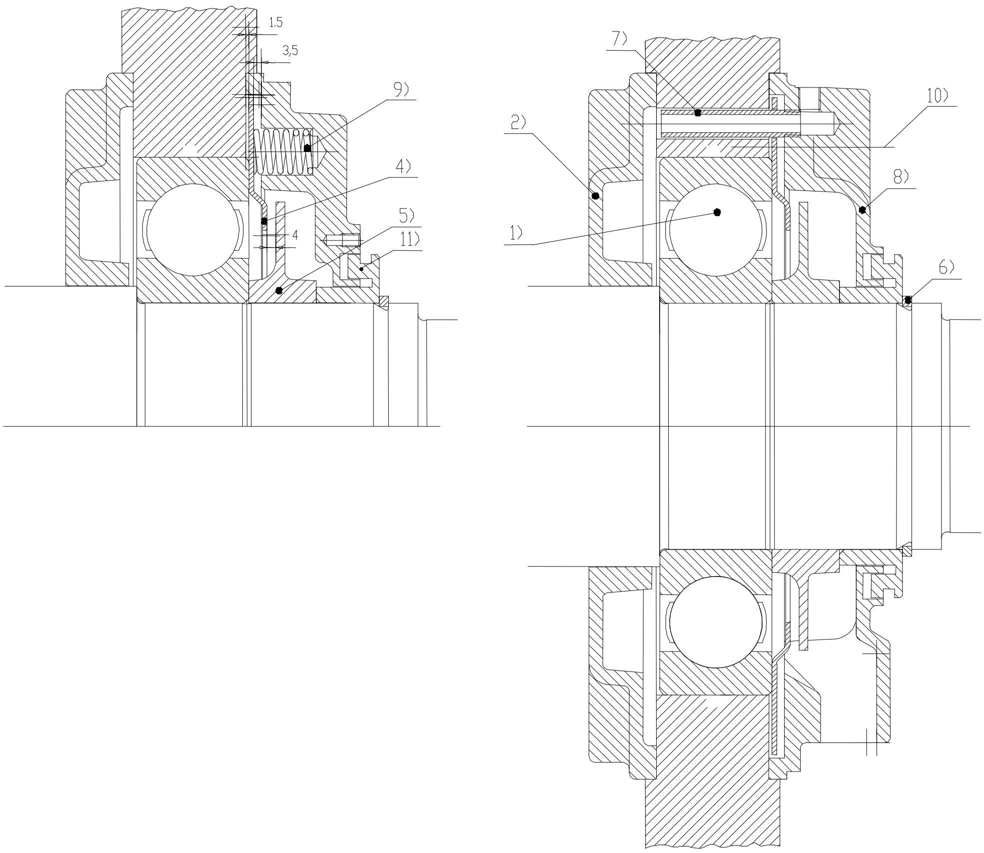


1	Ball bearing		6	Cirlip
2	Inner bearing cover		8	Outer bearing cover
4	Cover plate		10	Allen screw
5	grease valve		11	Labyrinth packing

NOTE! The screws are locked with loctite

Bearing construction for axially locked deep groove ball bearing

Appendix 3



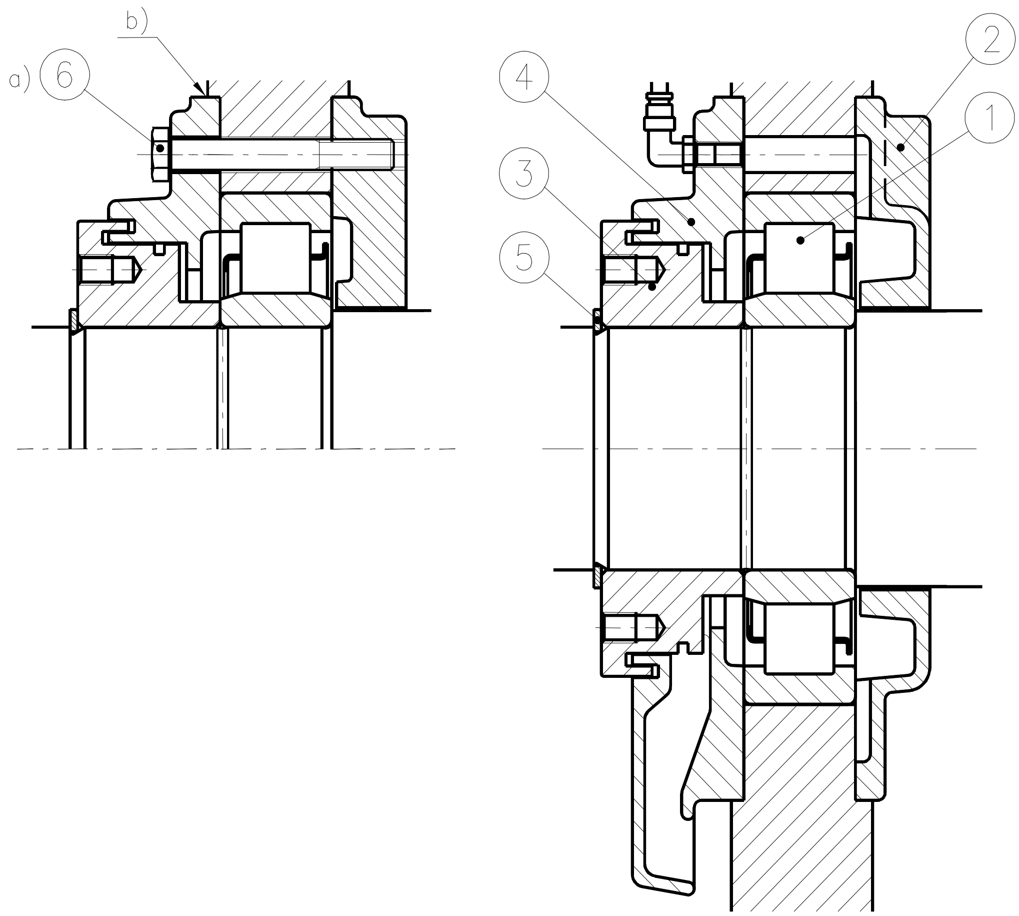
1	Ball bearing
2	Inner bearing cover
4	Cover plate
5	Grease valve
6	Cirlip

7	Grease pipe
8	Outer bearing cover
9	Spring
10	Allen screw
11	Labyrinth packing

NOTE! The screws are locked with loctite.

Bearing construction for axially free deep groove ball bearing

Appendix 4



1	CYLIND. ROLLER BEARING
2	INNER BEARING COVER
3	GREASE VALVE

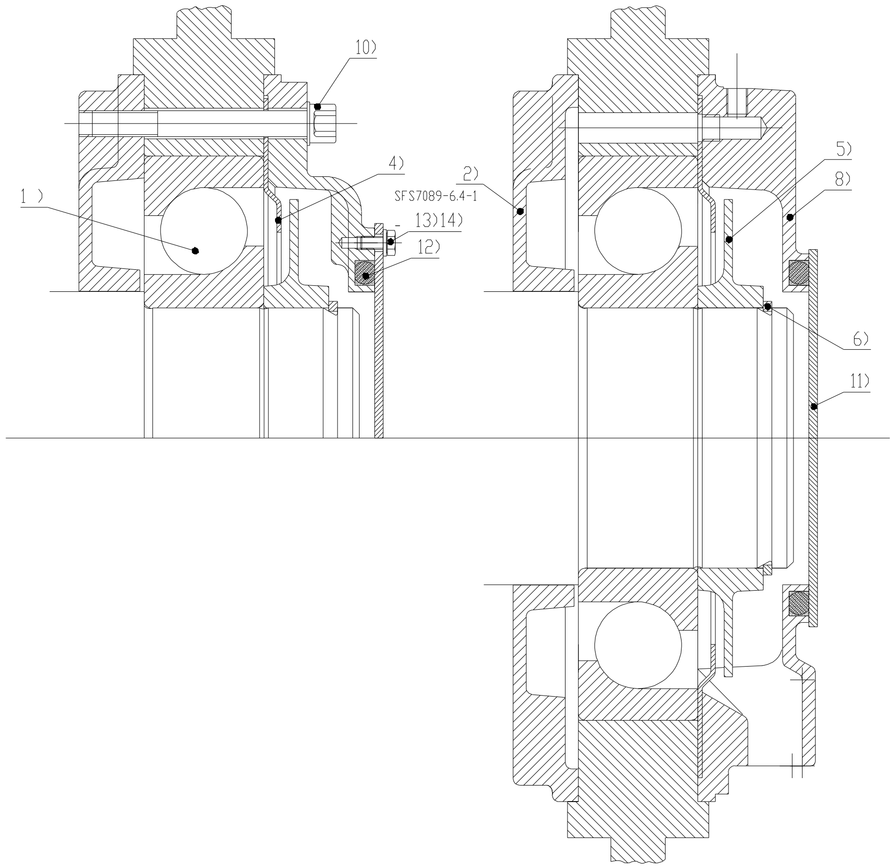
4	OUTER BEARING COVER
5	CIRCLIP
6	HEXAGON SCREW

a) Screws (item 6) are locked with locking agent.

b) Seal the surface between parts with sealing compound.

Bearing construction for cylindrical roller bearing

Appendix 5

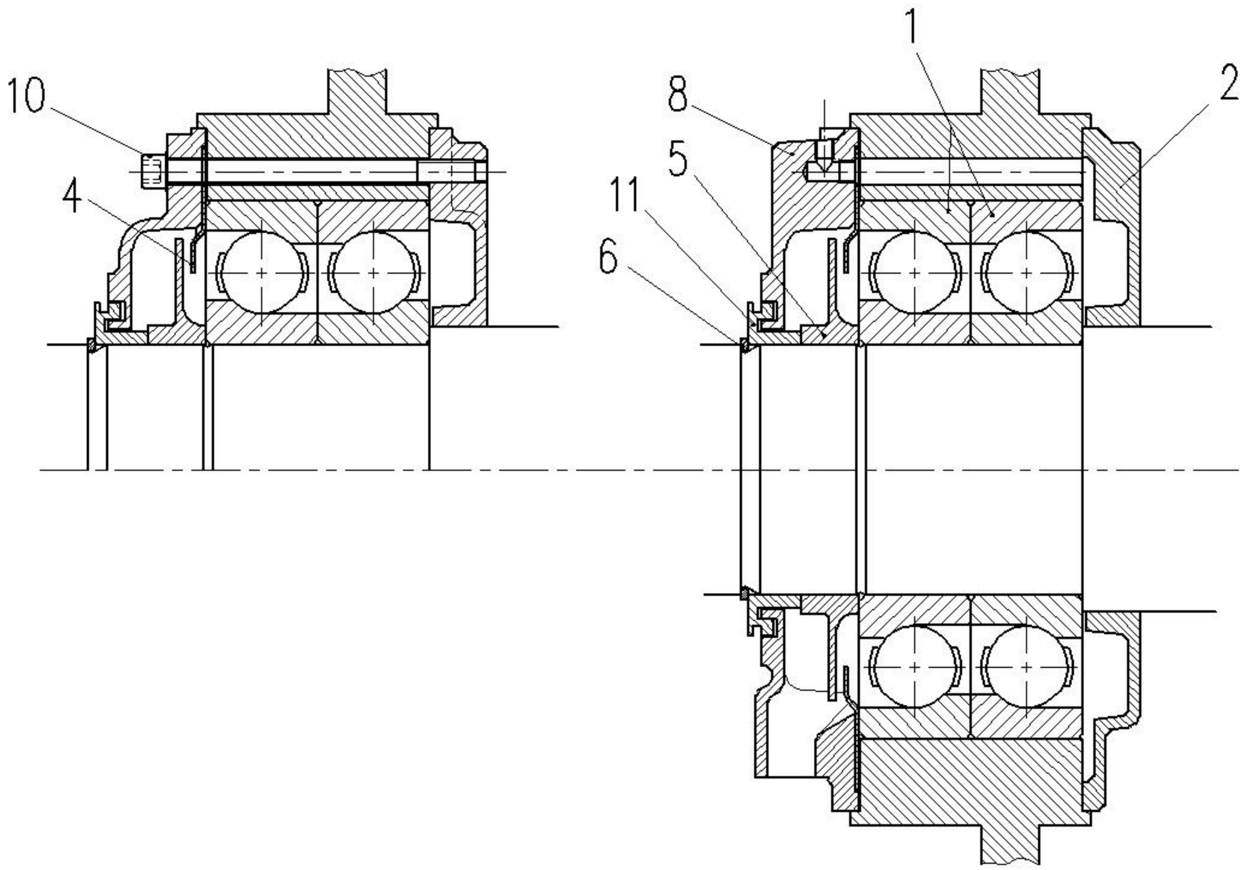


1	Angular contact ball bearing		10	Allen screw
2	Inner bearing cover		11	Cover
4	Cover plate		12	Oil ring
5	Grease valve		13	Hexagon screw
6	Circlip		14	Base plate
8	Outher bearing cover			

NOTE! The screws are locked with loctite

Bearing construction for angular contact ball bearing (vertical machines)

Appendix 6

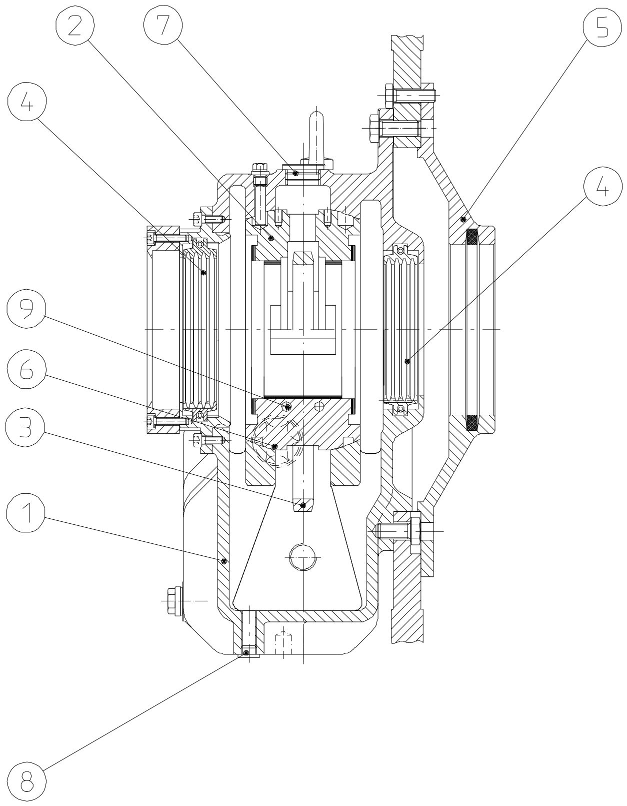


1	Ball bearing		6	Cirlip
2	Inner bearing cover		8	Outer bearing cover
4	Cover plate		10	Allen screw
5	grease valve		11	Labyrinth packing

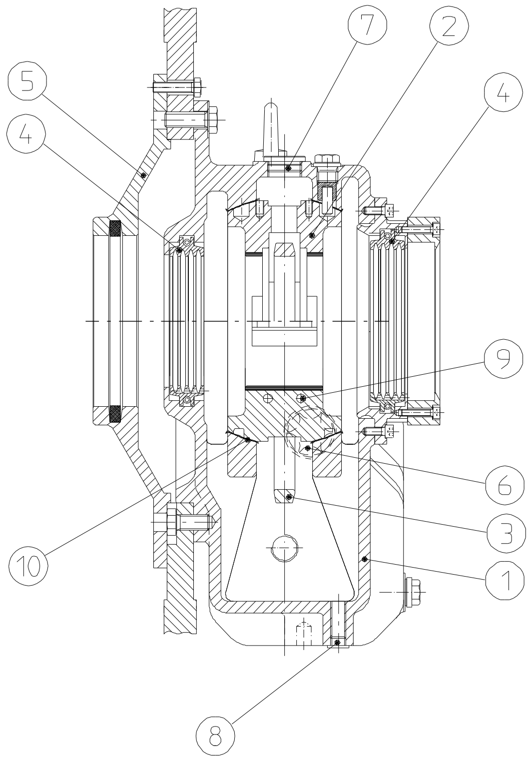
NOTE! The screws are locked with loctite

Bearing construction for angular contact ball bearing back to back mounting (for axial thrust)

Appendix 7



AXIALLY LOCATING BEARING

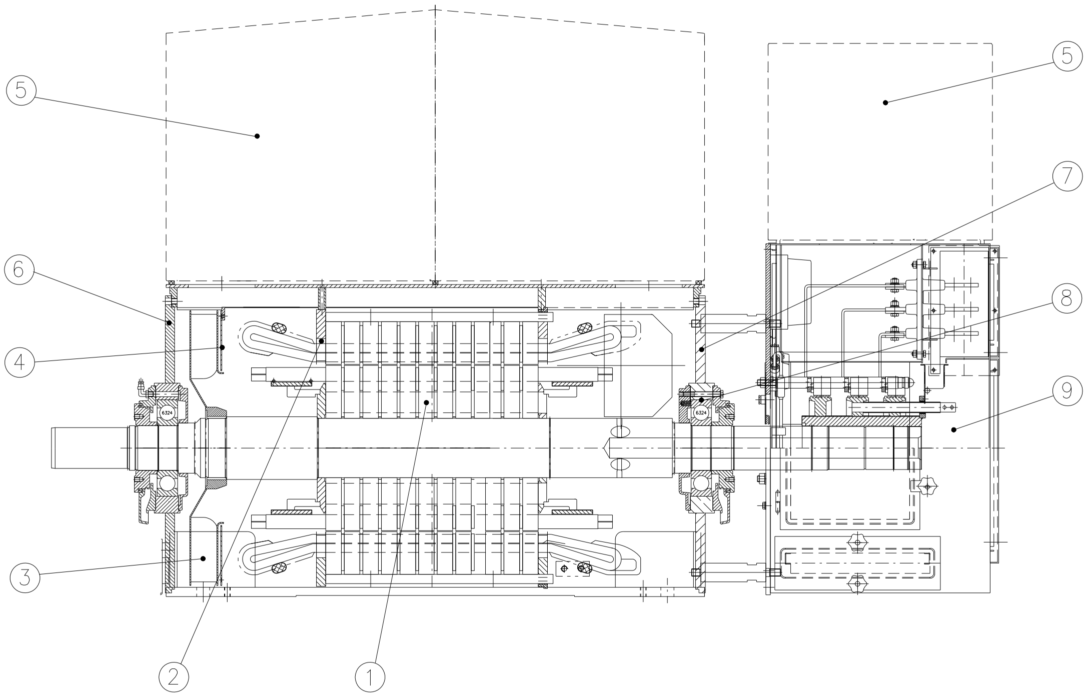


AXIALLY FREE BEARING

1	BEARING HOUSING	6	OIL SIGHT GLASS
2	BEARING SHELL	7	OIL RING SIGHT GLASS / OIL FILL PLUG
3	OIL RING	8	OIL DRAIN PLUG
4	LABYRINTH SEAL	9	THERMOMETER BORE POSITION
5	MACHINERY SEAL	10	INSULATED SHELL

Sleeve bearings

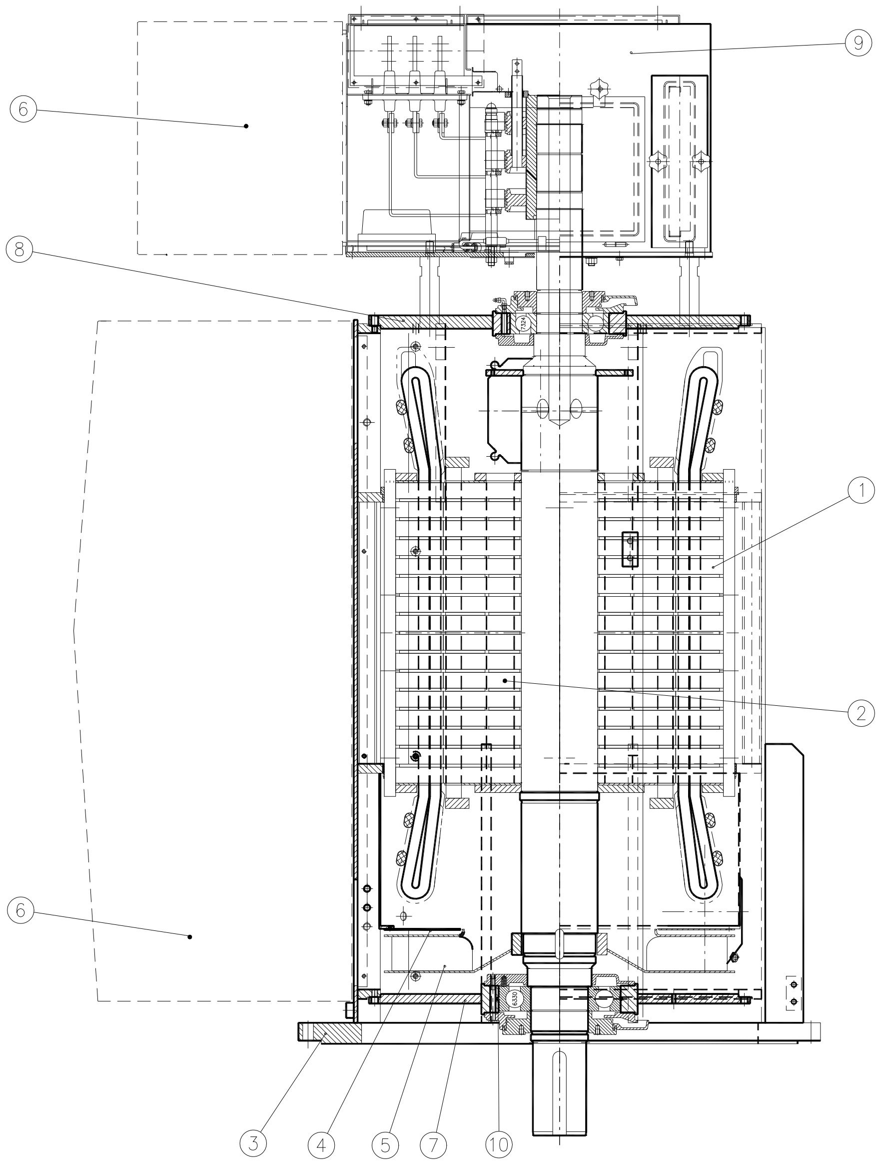
Appendix 8



1	ROTOR		6	D-END SHIELD
2	STATOR		7	N-END SHIELD
3	INNER FAN		8	O-RING
4	AIR GUIDE		9	SLIP RING UNIT
5	COOLING UNIT/UPPER COVER			

Sectional drawing of horizontal mounting machine with permanent contact type slip ring unit

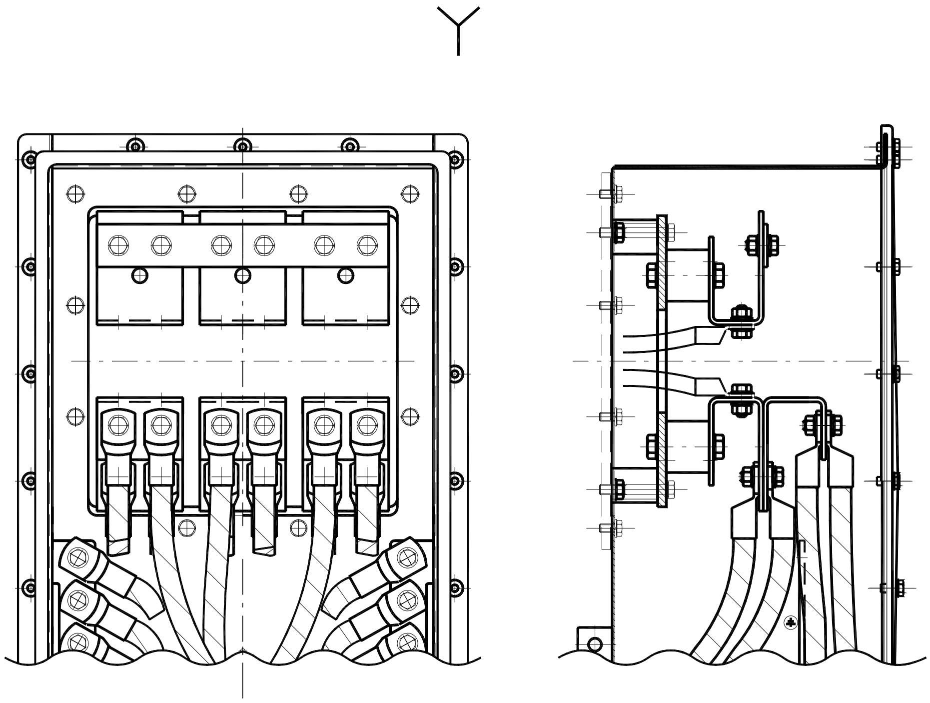
Appendix 9

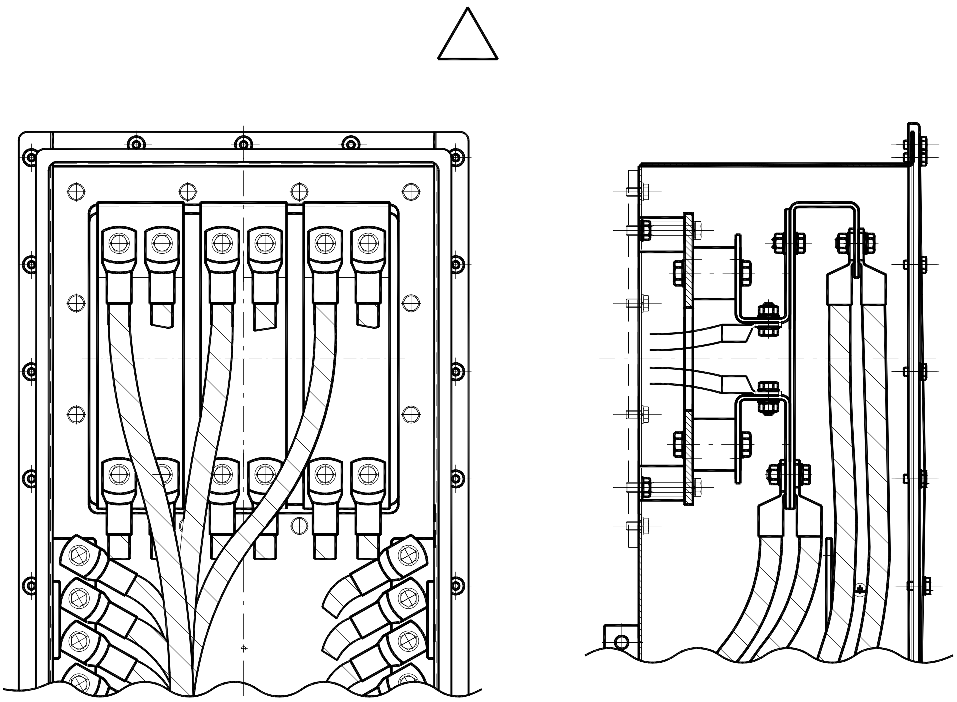


1	STATOR	6	COOLING UNIT
2	ROTOR	7	D-END SHIELD
3	END SHIELD STATOR LOCKING PIN	8	N-END SHIELD
4	AIR GUIDE	9	SLIP RING UNIT
5	INNER FAN	10	O-RING

Sectional drawing of vertical mounting machine with permanent contact type slip ring unit

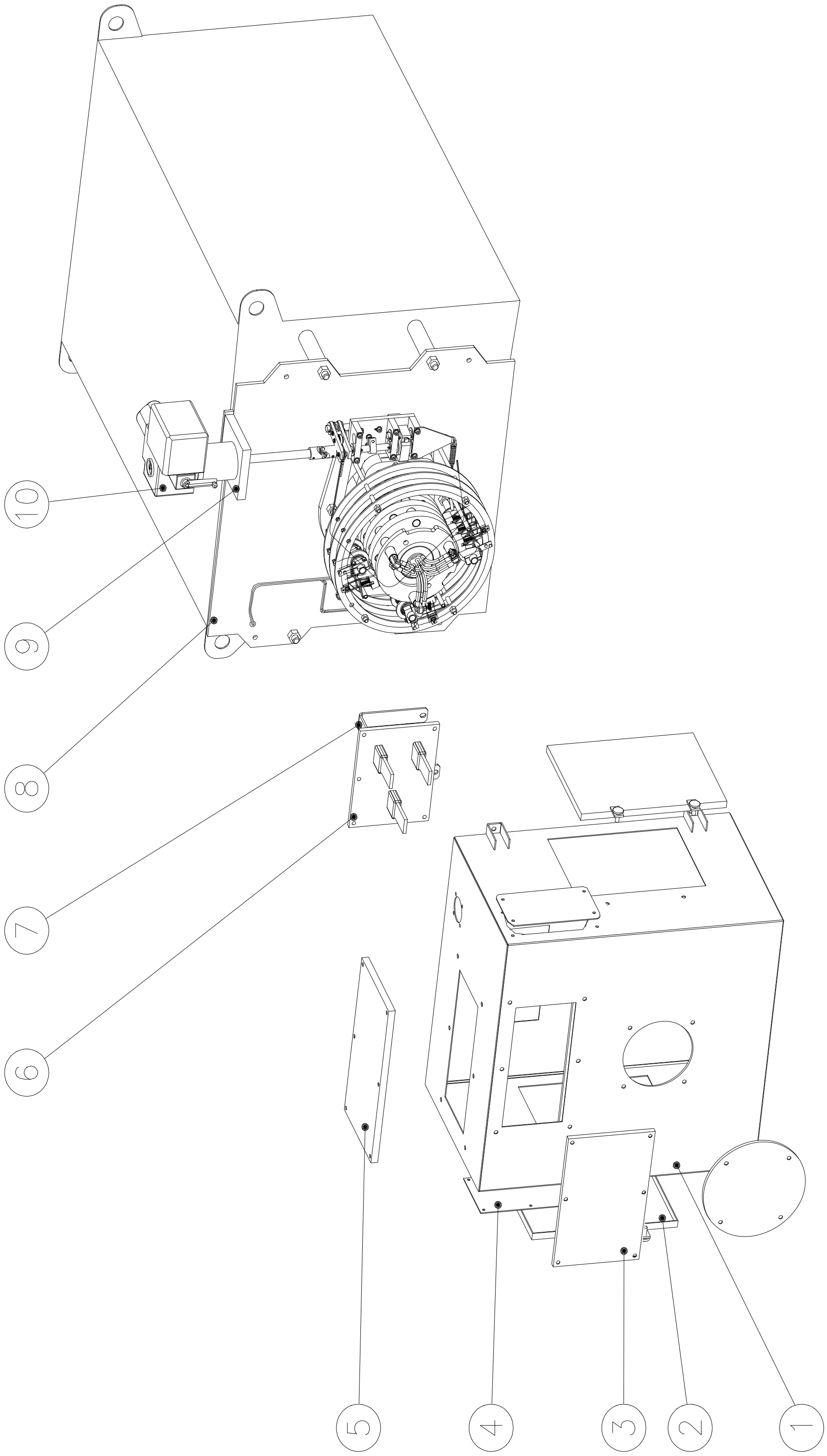
Appendix 10





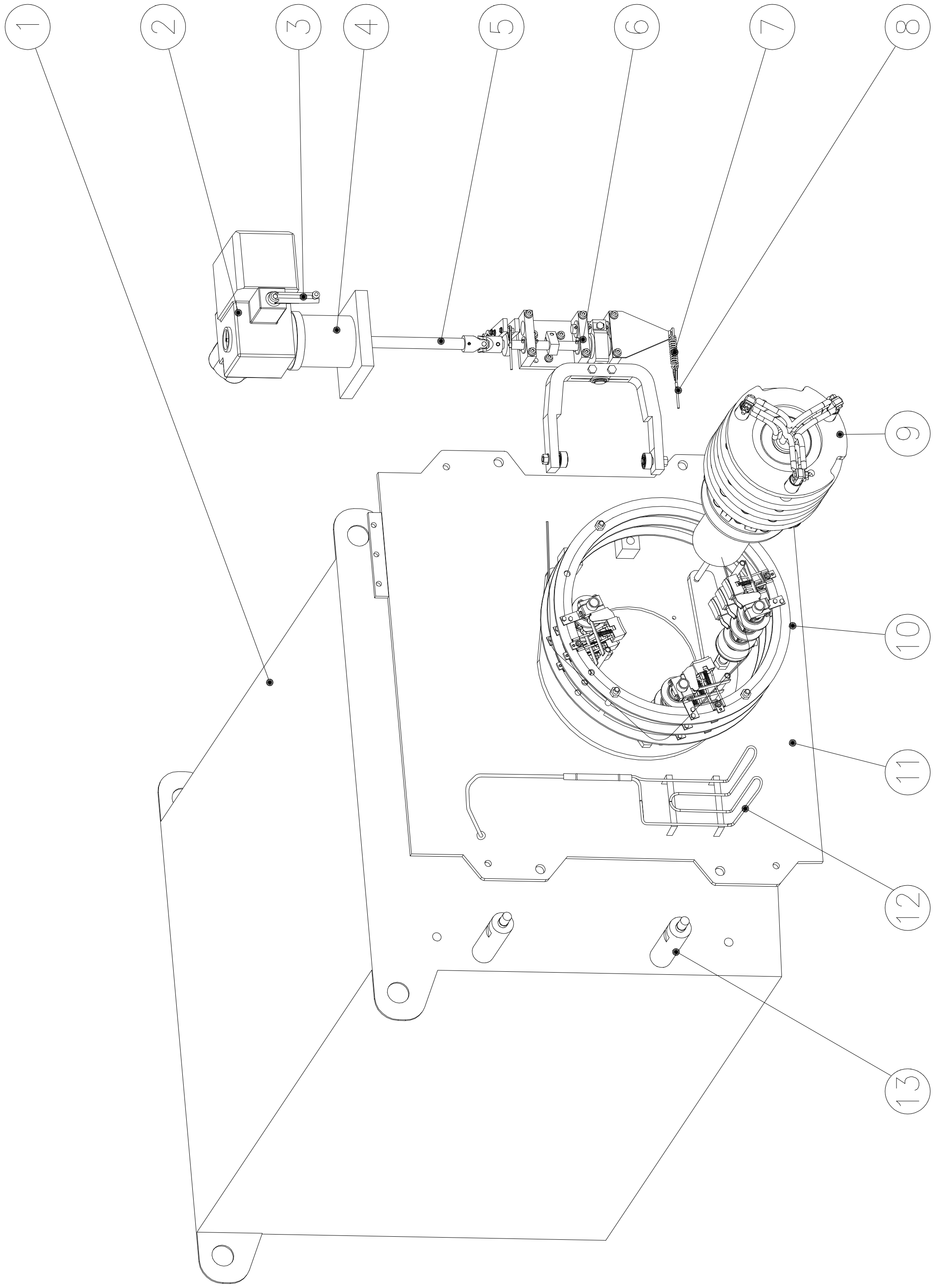
Star- and delta connections

Appendix 11



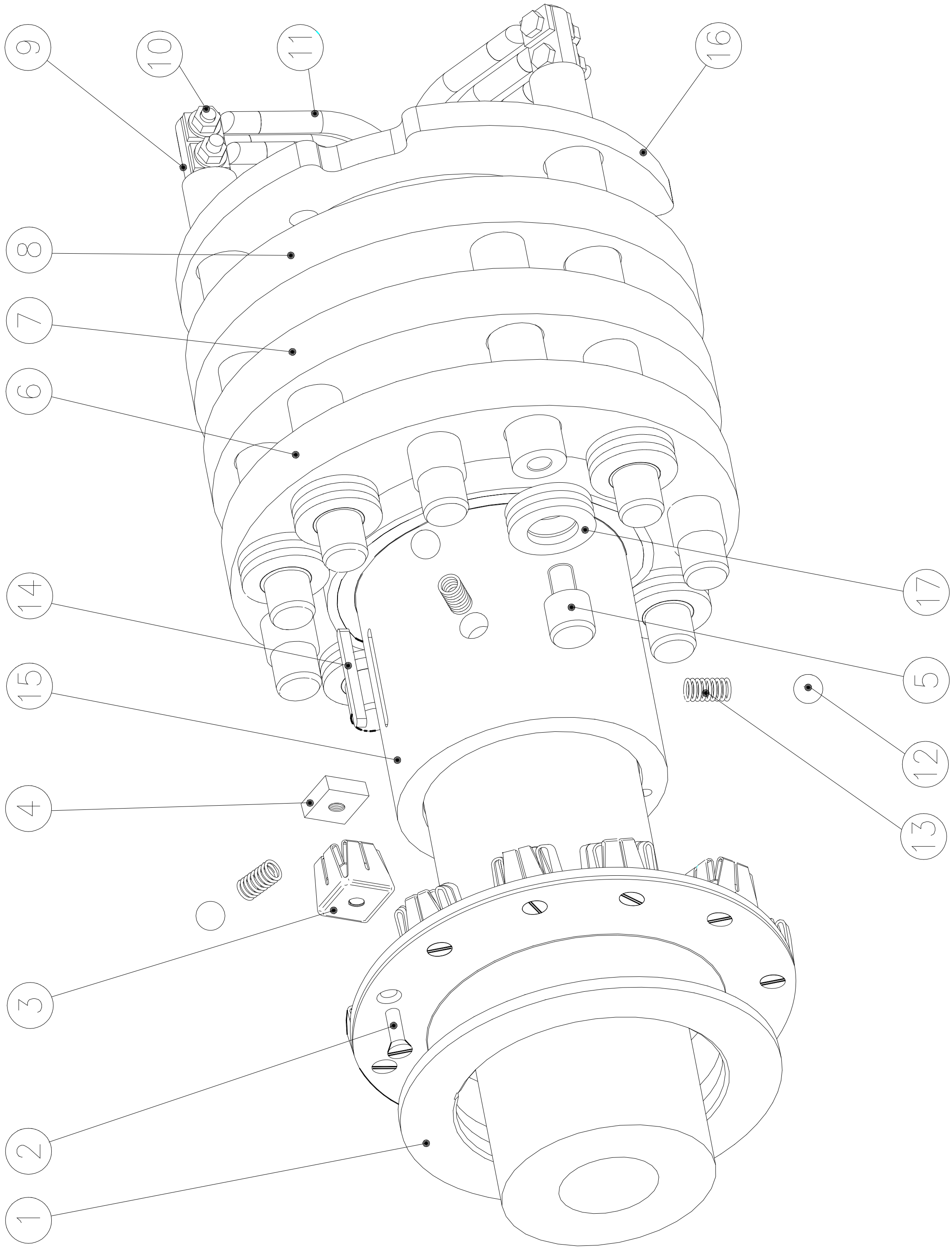
Housing Details

Appendix 12



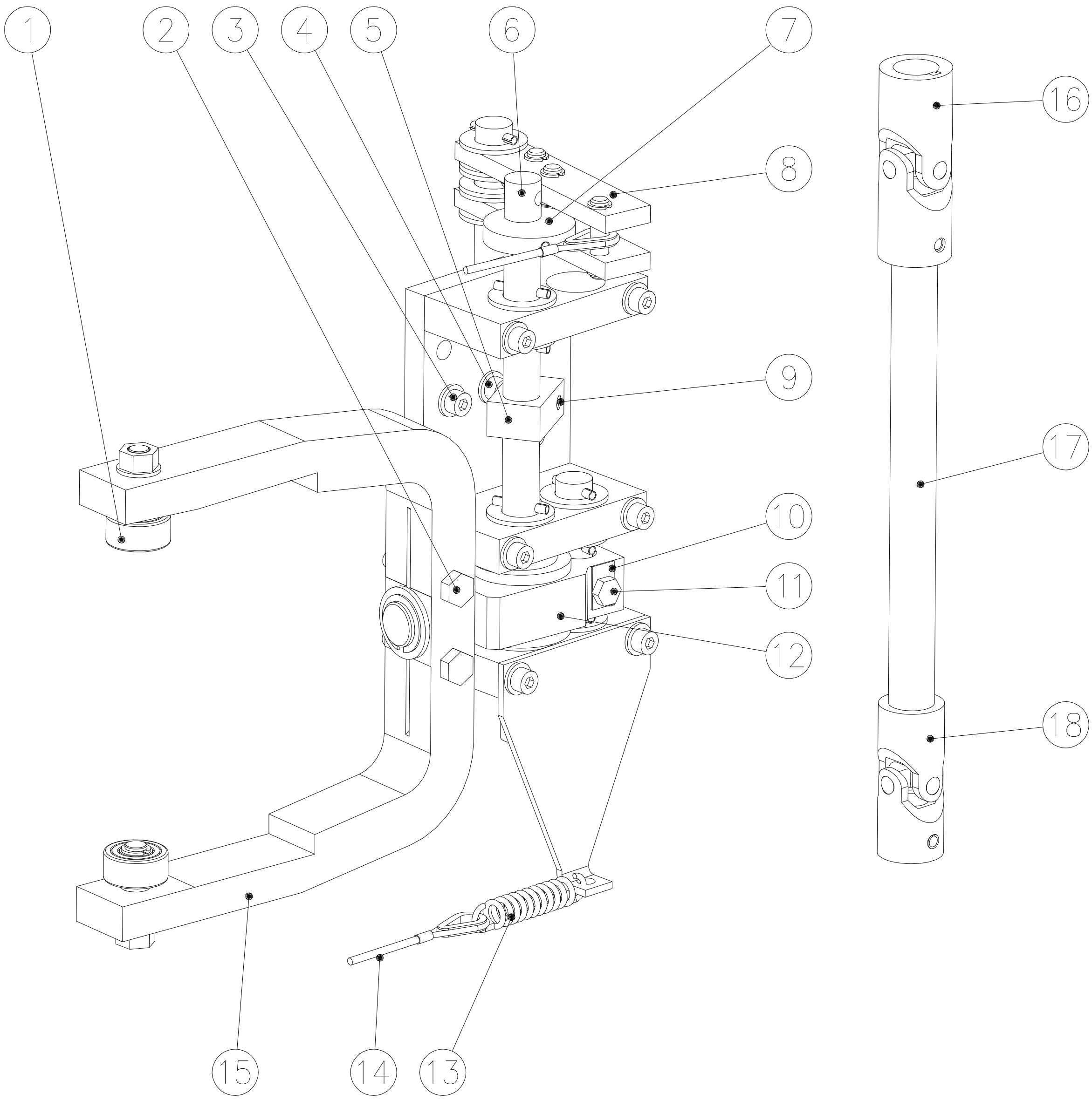
Slip Ring Gear

Appendix 13



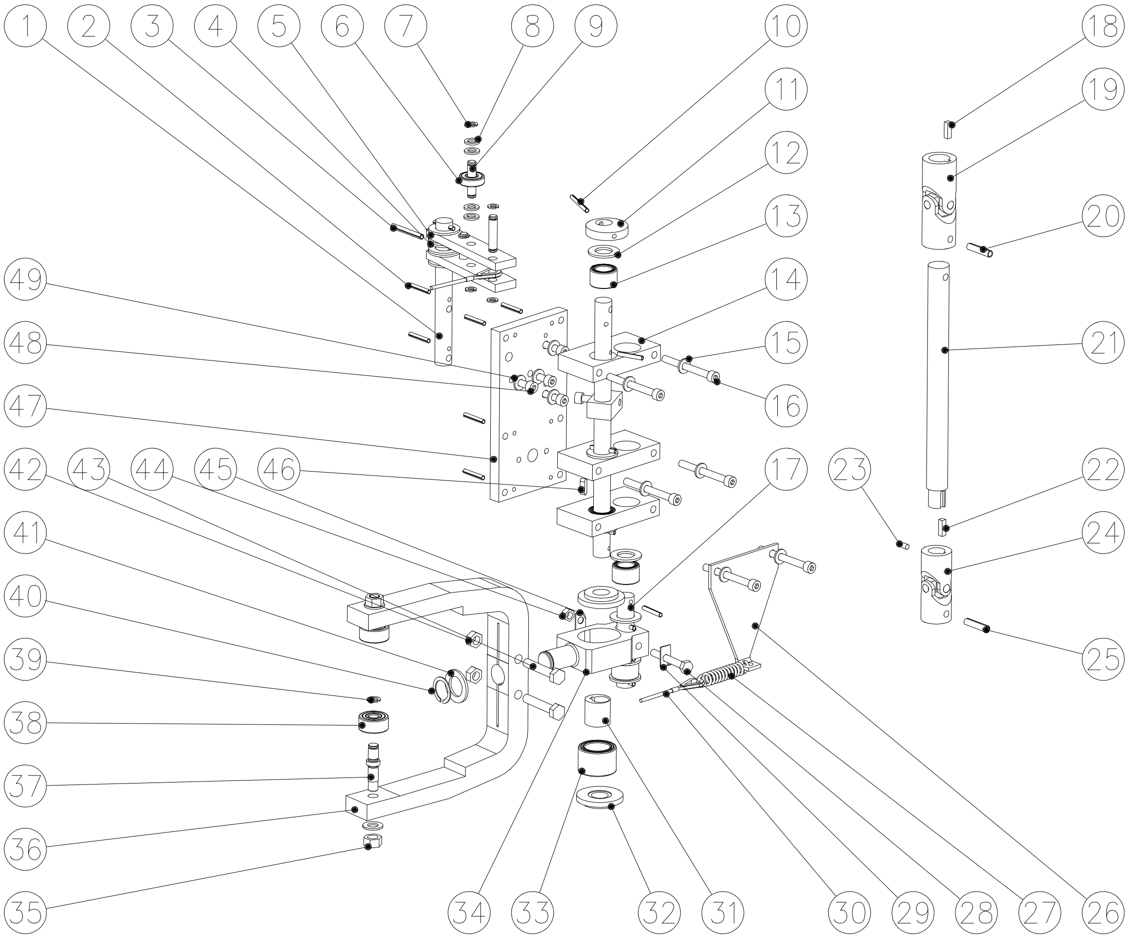
Slip Ring Assembly

Appendix 14



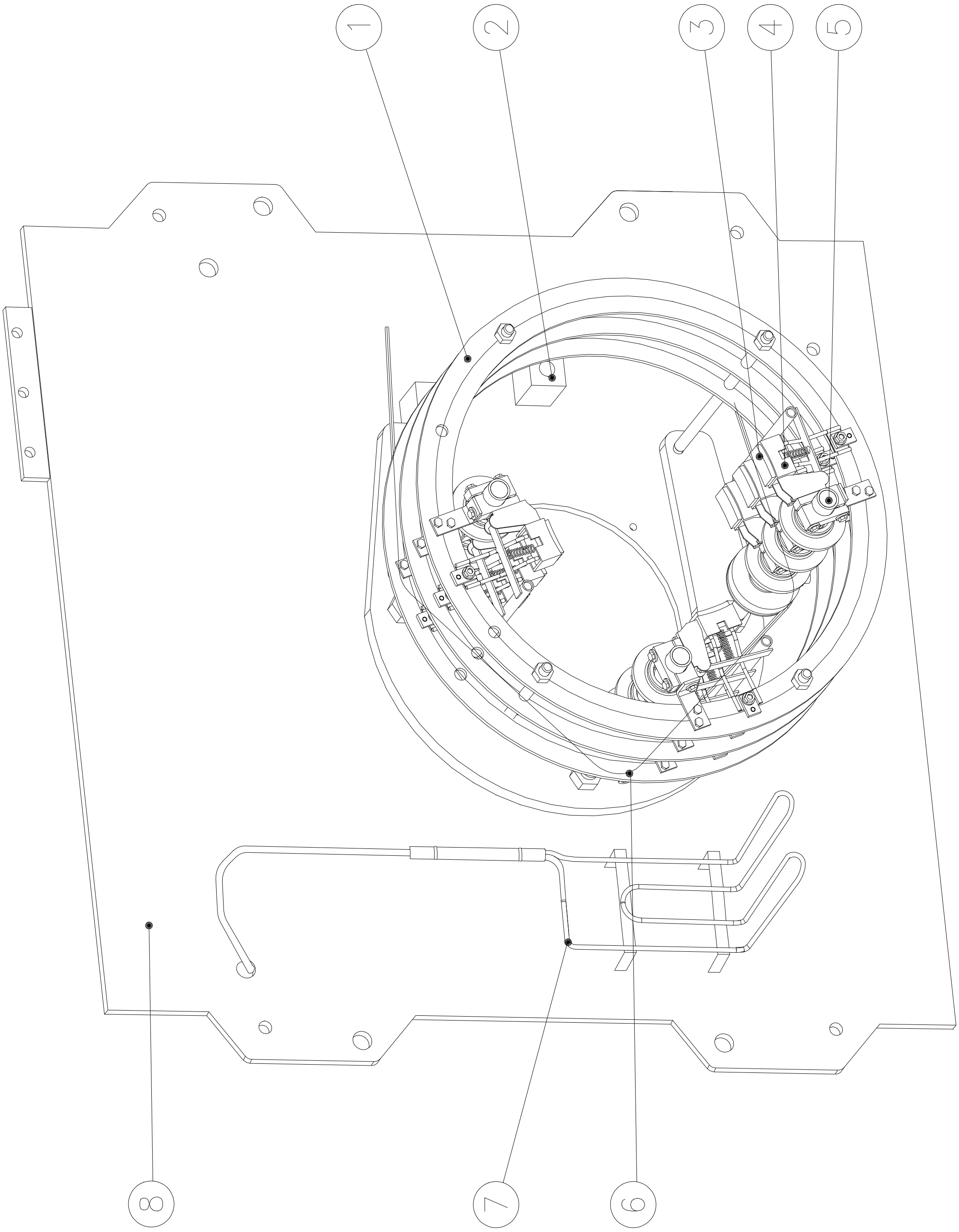
Brush Lifting Mechanism

Appendix 15



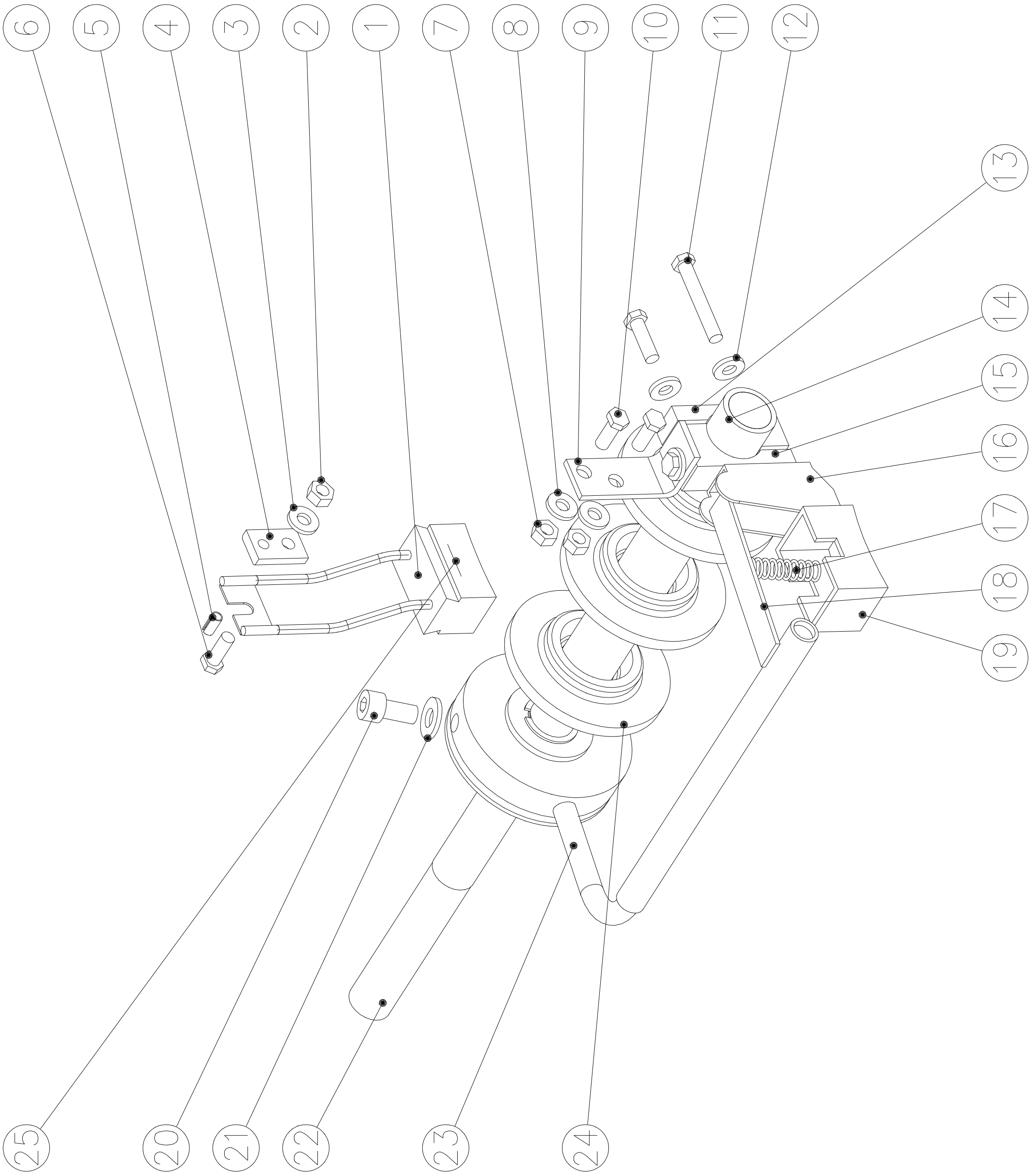
Brush Lifting Mechanism, Parts

Appendix 16



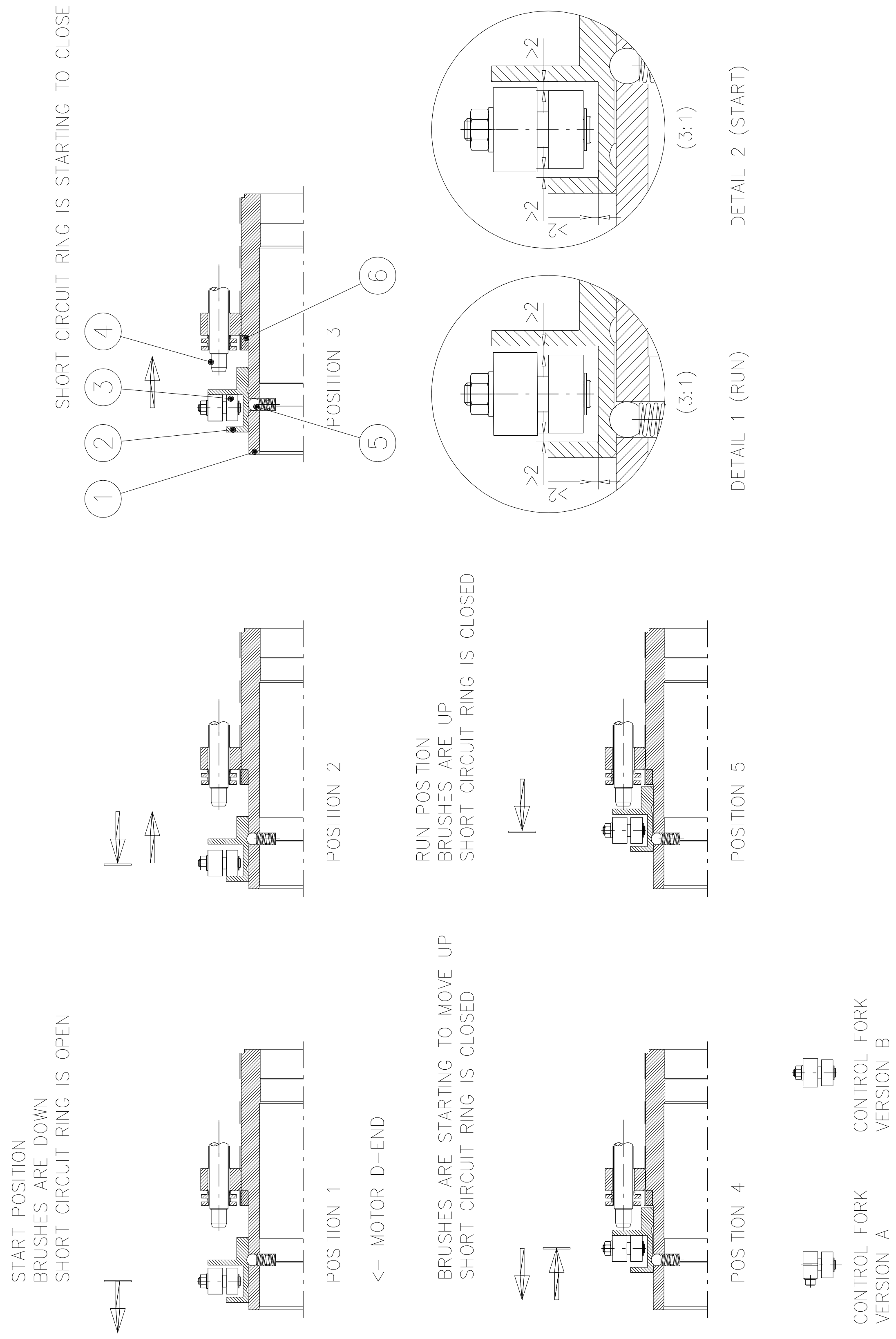
Brush Rocker

Appendix 17



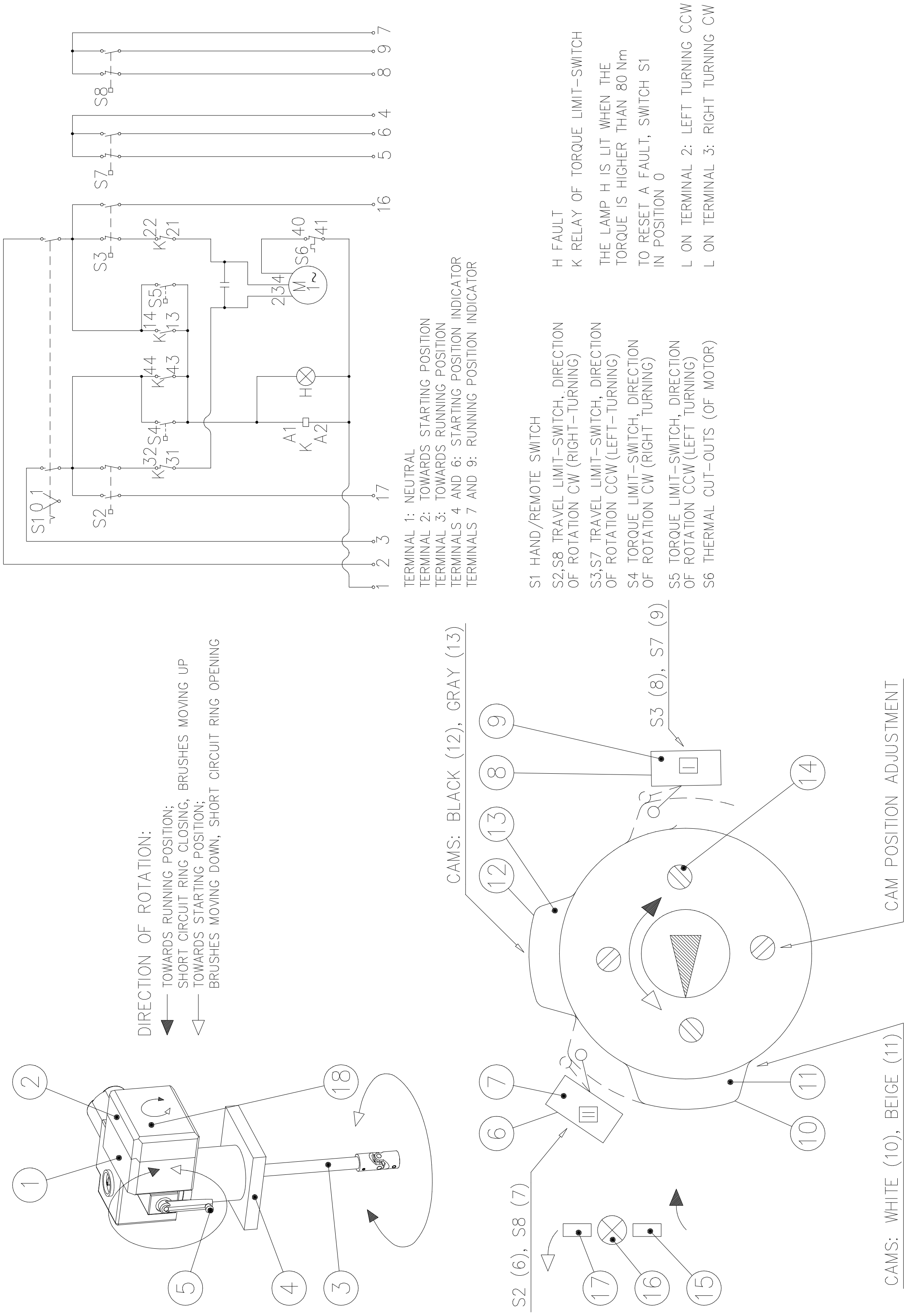
Brush Bolt

Appendix 18



Theory of Operation

Appendix 19



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