SIEMENS

SIMODRIVE

1FW6 Built-in Torque Motors

Configuration Manual

02.06 Edition

SIMODRIVE® Documentation

Printing history

Brief details of this edition and previous editions are listed below.

The status of each version is indicated by the code in the "Remarks" columns.

Status code in the "Remarks" column:

A .... New documentation.
B .... Unrevised reprint with new Order No.
C .... Revised edition with new version.

Version	Order No.	Remarks
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This book is included in the documentation on CD-ROM **(DOCONCD)**

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current	6FC5 298-0CD00-0BG0	**C**

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Microsoft Office 2000, Adobe Illustrator CS and the AutWinDoc documentation tool were used to generate this document.

The controller may support functions that are not described in this documentation. This does not, however, represent an obligation to supply such functions with a new control or when servicing.

We have checked the contents of this manual for agreement with the hardware and software described. Since deviations cannot be precluded entirely, we cannot guarantee complete conformance. The information given in this publication is reviewed at regular intervals and any corrections that might be necessary are made in the subsequent printings. We welcome any suggestions for improvement.

Technical data subject to change.

Order No. 6SN1 197-0AD00-0BP3
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Foreword

Information on SIMODRIVE documentation

This document is part of the documentation that has been developed for SIMODRIVE. All of the documents are available individually. The documentation list, which includes all Advertising Brochures, Catalogs, Overviews, Short Descriptions, Operating Instructions and Technical Descriptions with Order No., ordering location and price can be obtained from your local Siemens office.

This document does not purport to cover all details or variations in equipment, nor to provide for every possible contingency to be met in connection with installation, operation or maintenance.

We would also like to point-out that the contents of this document are neither part of nor modify any prior or existing agreement, commitment or contractual relationship. The sales contract contains the entire obligation of Siemens. The warranty conditions specified in the contract between the parties is the sole warranty of Siemens. Any statements contained herein neither create new warranties nor modify the existing warranty.

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Phone:	+49 (0) 180 / 5050 - 222
Fax:	+49 (0) 180 / 5050 - 223
Internet:	http://www.siemens.com/automation/support-request

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Explanation of symbols

In addition to the danger and warning concept that is explained in the Chapter "Safety information and instructions", additional notes are used in this documentation:

! **Important**

This symbol is used in the documentation if reference is made to important information and data.

Note

“Note” indicates important information about the product or respective part of the documentation that is essential to highlight.

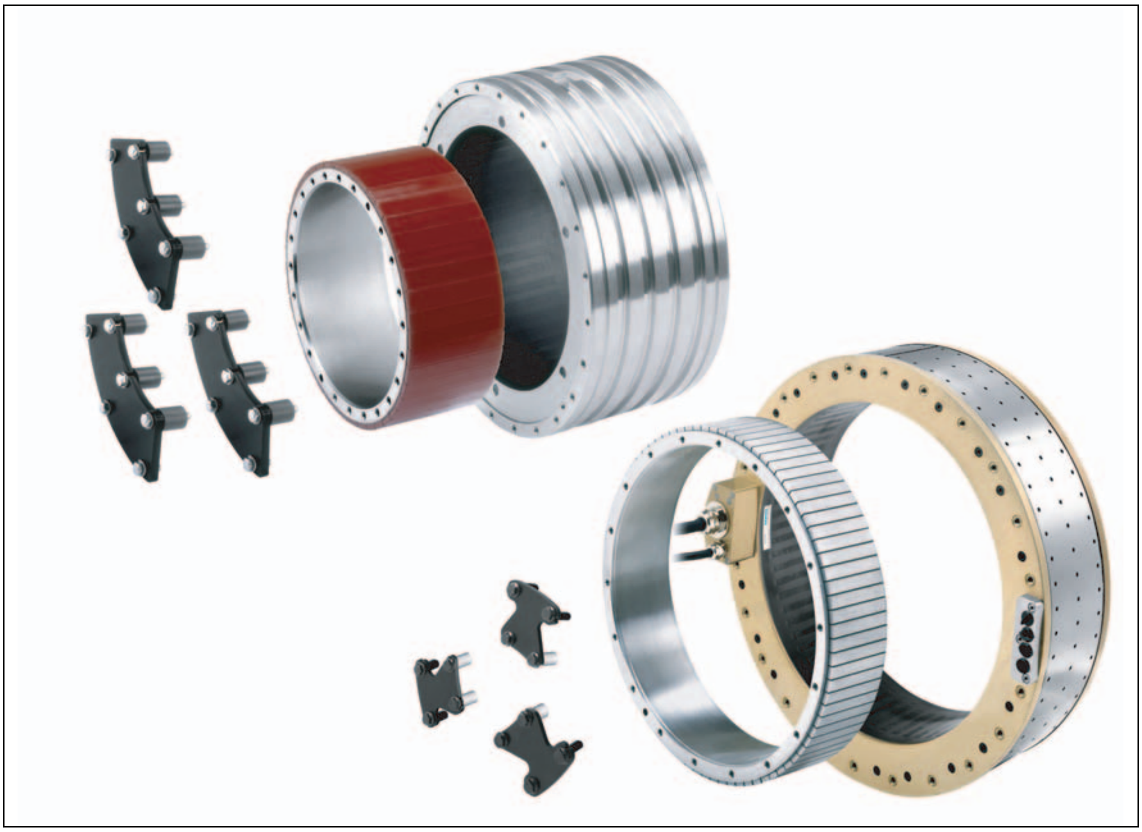
Using third-party products

This document contains recommendations relating to third-party products. Non-Siemens products whose fundamental suitability is familiar to us. It goes without saying that equivalent products from other manufacturers may be used. Our recommendations are to be seen as helpful information, not as requirements or dictates. We do not guarantee the features and characteristics of third-party products.

Dimensions

All dimension data are subject to production-related influences. This means that they can either not be guaranteed or only within the specified tolerances.

1FW6 built-in torque motors



Space for your notes

Contents

Space for your notes

1 Safety Information and Instructions 1

1.1 Danger and warning concept

The following symbols are used in this documentation to refer to dangers:

Danger

Indicates an imminently hazardous situation that, if not avoided, **will** result in death, serious injury, or substantial damage to property.

Warning

Indicates a potentially hazardous situation that, if not avoided, **may** result in death, serious injury, or substantial damage to property.

Caution

Indicates a potentially hazardous situation that, if not avoided, **may** result in minor personal injury or damage to property.

Caution

Used without the safety alert symbol, this indicates a potentially hazardous situation that, if not avoided, **may** result in damage to property.

Notice

Used without the safety alert symbol, this indicates a potential situation which, if not avoided, **may** lead to an undesirable result or state.

1.2 General safety information and instructions

The safety information and instructions described here apply for **built-in torque motors shipped as a complete unit**, which comprise, as a minimum a stator and a rotor. Special information must be taken into consideration when individual components are shipped. The local Siemens office must, under all conditions, provide support when it comes to handling individual components.

Please carefully observe **all** of the safety information and instructions in order to avoid injury and/or material damage. We would like to especially point-out the safety information and instructions and general information regarding the strong permanent magnets that are used in the rotors of the built-in torque motors.

The rotor is held in the stator using transport locks and a foil to maintain the appropriate clearance. In order to store and transport the built-in torque motors, the original packaging and the transport locks including the associated bolts are required – and these should therefore be stored in a safe place. Also keep this Configuration Manual and provide it to the authorized personnel when required.

Danger

If the safety information and instructions are not carefully observed and maintained, there is a danger of death, severe bodily injury and/or material damage.
It is absolutely mandatory that you carefully observe the safety information and instructions in this Configuration Manual – also the special safety information and instructions in the individual chapters.
Carefully observe all of the warning labels and reference labels!
Ensure that your final product complies with all of the associated Standards and legislation! Further, all of the relevant national and local plant/system-specific safety regulations and specifications must be taken into account.
The details in the catalogs and proposals apply, in addition to the safety information and instructions of this Configuration Manual when implementing special versions of these motors.
When carrying-out work on the drive converter system, also observe the information in the appropriate Operating Instructions!

1.2.1 Requirements placed on personnel

For the purpose of this document and product labels, a qualified person is a person who is familiar with the installation, mounting, start-up and operation of the equipment and hazards involved. He or she must have the following qualifications, e.g.:

- Training or instruction and authorization to energize, de-energize, ground, and tag circuits and equipment in accordance with established safety procedures
- Training or instruction in the proper care and use of protective equipment in accordance with established safety procedures
- Training in rendering first aid

Danger

There is a danger of death, severe bodily injury and/or material damage, if untrained personnel handle torque motors and/or their associated components.
Only personnel who know and observe the relevant safety information and instructions may handle torque motors and their associated components.
Only qualified trained personnel who have been appropriately instructed may mount/install, commission, operate and service these motors. This personnel must be completely knowledgeable regarding the contents of this Manual.
At least two technicians must be deployed when carrying-out any work due to the danger of crushing as a result of the strong magnetic fields (refer to Chapter "Hazards as a result of strong magnetic fields").

Important

Ensure that the information on the sources of danger and the safety measures are available at any time. Carefully archive all of the descriptive information and safety information and instructions relating to these torque motors and their associated components.
All of the descriptions and safety information and instructions can be requested from your local Siemens office.

1.2.2 Correct use

Danger

There is a danger of death, severe bodily injury and/or material damage, if torque motors and their associated components are not correctly used.

These motors have been designed for applications in industry or the trades. They correspond to the harmonized Standards of the series EN60034 (VDE 0530). It is **forbidden** to use this product in **hazardous zones** and areas (explosion protection) unless they have been **explicitly designed** for this purpose (carefully observe additional information and instructions). In a special situation – when used in plants and systems that are **not** of an industrial nature – increased requirements apply (e.g. shock hazard protection), then these conditions must be ensured on the plant side when the motors are mounted and installed.

Torque motors and their associated components may only be used for applications that have been clearly specified by the manufacturer. If you have any questions, please contact your local Siemens office.

Your local Siemens office must be contacted if special versions and construction types are applicable where the technical details deviate from the torque motors described here.

The motors are designed and dimensioned for ambient temperatures between – 5 °C and + 40 °C and installation altitudes $\leq$ 1000 m above sea level. The conditions at the location must coincide with all of the rating plate data and conditions specified in this Configuration Manual.

Following the results of a risk analysis, additional protection equipment on the machine or the system may be necessary to avoid endangering persons. In this case, especially the programming, parameterizing and wiring of the peripherals used, must correspond to the safety performance defined as a result of the necessary risk analysis.

It must be carefully ensured that the equipment is used for its intended purposes. The correct use of the equipment must be verified with a function test at the plant/system. This allows programming, parameterizing and wiring errors to be identified. The test results must be documented and if necessary entered into the relevant documentation that confirms the safety level.

1.2.3 Dangers as a result of strong magnetic fields

The rotors of torque motors have strong magnetic fields as a result of the permanent magnets. When powered-down, the magnetic field strength of torque motors results solely from the magnetic field of the motor. During operation, additional electromagnetic fields are present due to the stator.

Danger

Strong magnetic fields can directly effect persons and cause injury and damage.

In the Federal Republic of Germany, BGV B11 "Electromagnetic fields" must be carefully observed! Further, all of the relevant national and local regulations and specifications must be carefully taken into account.

Persons with heart pacemakers, metal implants and magnetic or electrically conductive foreign bodies are not permitted to handle torque motors and rotors. A detailed medical investigation is required for any exceptions to this rule. As a result of the magnetic fields and the workplace, clear access rules must be enforced and the limits of the permissible safe working area must be clearly identified.

Forces of attraction to materials that can be magnetized

Humans cannot detect strong magnetic fields and generally do not have experience in handling them. Often, they do not expect that materials, which can be magnetized, and magnets can be suddenly drawn towards these magnetic fields.

In the proximity of the rotor (distance of less than 100 mm), magnetic forces of attraction of several kN can occur. – This corresponds, e.g. to have having a weight of several 100 kg on a human foot!

Danger

Strong forces of attraction to materials that can be magnetized result in a high danger of crushing when working close to the rotor (distance of less than 100 mm).
Never underestimate the level of these forces of attraction!
Never carry an object out of a material that can be magnetized (e.g. steel or iron) and/or permanent magnets (e.g. a second rotor) close to a rotor!
To deal with accidents when working with permanent magnets, the following must be immediately close at hand to release clamped parts of the body (hand, finger, foot):

- A hammer (approx. 3 kg) manufactured out of a tough material that cannot be magnetized
- Two wedges (wedge angle approx. 10° -15°) manufactured out of a tough material that cannot be magnetized (e.g. a hard wood)

It must be absolutely ensured that the wedges and hammer are suitable for these operations.

Danger

Danger as a result of electric shock! If a torque motor, already mounted in the bearings rotates, then hazardous voltages can be induced at the cable ends of these motors.
Either isolate the terminals and conductors of open cable ends or ensure that torque motors that are already located in their bearings cannot rotate.
Further, there is a danger of crushing!

Caution

Magnetic fields can result in data loss on magnetic and electronic data mediums and damage watches and clocks.
If you are close to a rotor (<100 mm) do not carry magnetic or electric data mediums (e.g. credit cards, floppy disks, etc.) and do not weear a watch!

1.2.4 Immediate measures for accidents involving permanent magnets

- Keep calm!
- Press the EMERGENCY STOP button if the machine is powered-up
- Carry-out/request FIRST AID
- Prise apart components that are clamped together to free body parts that have been trapped (hand, finger, foot...)
    - using the hammer drive the wedge to prise open the components
    - release the body part (hand, finger, foot...)
- If necessary, call a DOCTOR

1.2.5 Attaching warning and prohibition signs/labels

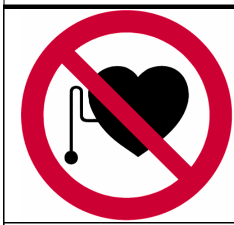
All of these dangerous locations must be clearly identified directly close to the hazard using warning and prohibit labels and plates that are easily seen (pictograms). The texts used on these labels and plates must be in the language of the country in which the equipment is finally installed.

The following permanent adhesive labels are provided for this purpose:

Table 1-1: Warning labels and plate supplied according to BGV A8 and DIN 4844-2 and their significance

Label	Meaning	Label	Meaning
	Warning against magnetic fields (D-W013)		Warning against injury to hands (D-W027)
	Warning against hazardous electrical voltage (D-W008)		Warning against hot surfaces (D-W026)

Table 1-2: Prohibit labels and plates supplied according to BGV A8 and DIN 4844-2 and their significance

Label	Meaning	Label	Meaning
	Prohibited for persons with heart pacemakers (D-P011)		Prohibited for persons with metal implants (D-P011)
	Prohibited to carry/wear metal parts and watches (D-P020)		Prohibited to carry magnetic or electronic data media (D-P021)

1.3 Special safety information and instructions

To ensure perfect and safe operation of torque motors, it is absolutely essential that they are correctly transported, correctly stored, installed and mounted and serviced and are protected against dirt and contact with aggressive substances.

1.3.1 Information and instructions on packaging, storage and transport

When packing/unpacking and transporting torque motors or rotors, ensure that no danger is incurred as a result of strong magnetic fields of the rotors – also refer to the Section "Hazards as a result of strong magnetic fields"

Danger

If incorrectly packed, stored and/or transported, there is a danger of death, bodily injury and/or material

Personnel must understand and observe the safety information and instructions for storage and transport.

When transporting motors or parts of motors, axes that can accidentally move because there is no self-locking mechanism must be locked to prevent them rotating!
Danger when hoisting and transporting the equipment!
Incorrect execution, unsuitable or damaged equipment can result in injury and / or material damage.

Hoisting/raising equipment, transport vehicles and load suspension equipment must be in full compliance with the applicable regulations.

Carefully observe IATA regulations when transporting equipment in aircraft!

Locations where rotors are stored must be clearly marked using pictograms according to Table 1-1 and Table 1-2.

Keep storage locations dry and protect them from heat and cold!

Carefully observe warning information on the packaging!

Always wear safety shoes and the appropriate working gloves!

Never store or transport built-in torque motors and rotors when they are unpacked!
Only use the undamaged original packaging!
Damaged packaging must be immediately replaced. If the rotor is not correctly packed, then there is no protection against the rotor attracting objects in its immediate vicinity. In addition, when storing and moving the rotor, hazardous motion can occur.

Important

If at all possible store the packaging materials that are used for the torque motors and rotors! You can request the original packaging materials from your local Siemens office.

Danger

Danger of toppling! When stacking motors, stators and rotors there is a danger of death, bodily injury and/or material damage.

It is not permissible to stack packed or unpacked motors, stators and rotors.
Only store and transport motors and rotors in a horizontal position.
Carefully observe all of the warning information and handling information on the packaging!

1.3.2 Information and instructions when installing built-in torque motors

Danger

When installing torque motors, work must be carried-out in close vicinity to the unpacked rotor. The hazards involved are especially high as a result of the strong magnetic fields

It is absolutely necessary that you carefully observe the safety information and instructions and information in this Configuration Manual.

The packaging of the built-in torque motor may only be removed immediately before installing and not before.

Never remove the transport locks at both ends if the built-in torque motor has not been mounted.

Two technicians must always be involved in the mounting work.

Use the mounting equipment provided.

Never place the magnetic surfaces onto metal and vice versa.

Never bring any objects that can be magnetized and / or permanent magnets close to the surfaces of the magnets.

Never use any tools that can be magnetized. If these tools are required, then they must be held tightly in both hands and slowly brought towards the built-in torque motor / rotor.

Danger as a result of electric shock! If a torque motor, already mounted in the bearings rotates, then hazardous voltages can be induced at the cable ends of these motors.
Either isolate the terminals and conductors of open cable ends or ensure that torque motors that are already located in their bearings cannot rotate.
Further, there is a danger of crushing!

Mounting work may only be carried-out when the equipment is in a no-voltage condition.

When mounting individual components, special equipment must be used and very specific procedures carefully applied. In this case, **it is mandatory that the local Siemens office provides the appropriate support.**

Caution

Sharp edges can cause cuts.
Always wear working gloves!

Caution

Falling objects can cause foot injuries.
Always wear safety shoes!

Warning

Defective connecting cables can result in electric shock and/or material damage - e.g. due to fire.
When installing the connecting cables please observe the following:

- they may not be damaged,
- they may not be subject to any strain,
- they may not come into contact with rotating parts.

Please carefully observe the permissible bending radii according to the Chapter "Interfaces".

1.3.3 Information and instructions on the electrical connections

Danger

Parts of electric equipment can be at hazardous voltage levels. There is a danger of electric shock!

When the rotor rotates, a voltage is present at the motor terminals that increases linearly with the voltage. At the no-load speed, the amplitude of the voltage at the motor terminals corresponds to the voltage of the drive converter DC link voltage.

Only trained electrical technicians may carry-out electrical work and only when the motor is at an absolute standstill!
Carefully observe all of the regulations for working with electrical equipment!
It is especially important to carefully observe the safety rules when working on electrical equipment according to EN 50110-1 (DIN VDE 0105-100):

- Only work with the equipment in a no-voltage condition
- Disconnect the system from the power supply
- Lock-out to prevent reclosure
- Ensure that the equipment is in a no-voltage condition
- Ground and short-circuit
- Cover or partition off adjacent components that are still under voltage
- Provide permission for work to commence
- First connect the protective conductor and as a last step, disconnect it!

The Temp–S and Temp–F circuits do not have "protective separation" - in accordance with VDE 0160 EN 50178 – neither with respect to one another nor to the power circuits. The operating company must ensure an adequate level of protective separation. Carefully observe the information and data in this Configuration Manual.

Danger

There is a danger of death, severe bodily injury (electric shock) and/or material damage if torque motors are incorrectly connected-up.

Torque motors must be connected-up according to the circuit diagram in the Configuration Manual. They must not be connected directly to the three-phase supply as this would destroy them.
Please carefully observe the documentation provided with the drive converter system!

Note

It is not permissible to connect SIMODRIVE drive units with three-phase motors to a line supply using residual-current protective devices (permissible according to EN 50178, Section 5.2.11). When operational, protection against direct contact is provided as the equipment is suitable for installation in general production areas (DIN VDE 0558 Part 1 / 07.87, Section 5.4.3.2.4).

A high-voltage test is carried-out in the routine test on all SIMODRIVE units with three-phase motors in conformance with EN 50178. When carrying-out a high-voltage test on the electrical equipment of industrial machines, all of the connections must be removed or disconnected in order that sensitive electronic components in the SIMODRIVE unit are not damaged (permissible according to EN 60204-1, Section 19.4). Also carefully observe the warning information and the description to check/test the insulation resistance using high voltage in the Chapter "Information and instructions on inspection, maintenance and repair".

1.3.4 Information and instructions for commissioning

Danger

There is a danger of death, severe bodily injury and/or material damage, if a motor is commissioned that does not comply with recognized safety specifications.

Torque motors are components that are built-into machines in the sense of the Machinery Directive 98/37/EC. Commissioning is absolutely prohibited until it has been completely ensured that the machine, in which the torque motor is to be installed, is in full compliance with the Machinery Directive 98/37/EC.

Equipment and machines equipped with low-voltage three-phase motors fed from drive converters must be in compliance with the protective requirements specified in the EMC Directive 89/336/EEC. It is the responsibility of the plant construction company/equipment construction company to ensure that the installation is compliant with all of the appropriate regulations. Shielded signal and power cables must be used. The EMC information and instructions of the drive converter manufacturer must be carefully observed!

Danger

There is a danger of death, severe bodily injury and/or material damage if the motor unintentionally starts.

Danger due to a spinning rotor! Never work in the area around the motor when it is powered-up.
Keep personnel away from areas that represent potential danger due to rotating parts and crushing!
Ensure that the motor is free to rotate.
Check the commutation before powering-up the system! Also observe the instructions to commission the drive converter system being used!
Limit motor currents.
Set the speed limit to a low value.
Monitor end positions.

Warning

The motor surfaces can reach temperatures of over 100 °C (212 °F). Danger of burns!

If a cooling system is being used ensure that it is operating correctly!
Do not touch the motor when being used or after it has been used!
Temperature-sensitive components (electric cables, electronic components) may not come into contact/touch hot surfaces.

Notice

The motor can overheat if temperature protection is not used.
Before powering-up for the first time (e.g. when testing), ensure that the temperature protection is effective!

1.3.5 Information and instructions on operation

Danger

Machine parts that are driven by torque motors represent a significant potential of causing injury as a result of the extremely high speeds and acceleration rates as well as the low friction and low level of self-locking - e.g. as a result of crushing.

Keep personnel away from the traversing and crushing zones of the axes!

Caution

If the torque motor is not correctly operated this can result in significant material damage.

Operation is only permissible at locations that are completely protected from the weather: The environment must be dry and protected against heat and cold.
Prevent foreign bodies from entering the motor space (chips, particles, liquids, oils, screws, tools etc.)!
Pay special attention to noise. If you hear any unusual noise, please contact your Siemens office immediately.
If precision problems occur at the workpiece then among other things, check that the rotor is free to move and also check the current consumption of the motor. Precision problems can have other causes - e.g. as a result of the mechanical machine design.
Ensure that the torque motor cooling system is functioning correctly.

1.3.6 Information and instructions on inspection, maintenance and repair

Danger
There is a danger of death, severe bodily injury and/or material damage if work is carried-out with the motor powered-up. Before carrying-out any work in the range of rotation of the motor, always power-down the motor (ensure that it really is in a no-voltage condition)

When carrying-out work in the range of rotation, always ensure that the motor is absolutely in a no-current and no-voltage condition in order to avoid any unintentional rotary motion!
Any work carried-out on the electrical equipment must be done with it in a no-current and no-voltage condition in order to avoid electric shock!

Danger

There is a danger of death, severe bodily injury and/or material damage when disassembling.

When disassembling/removing the motor, the information and instructions provided under Chapter "Information when mounting the built-in torque motor" must be carefully observed.

Caution

Sharp edges can cause cuts.
Always wear working gloves!

Caution

Falling objects can cause foot injuries.
Always wear safety shoes!

Danger

There is a danger of burning when hot surfaces are touched after the motor has been operational.

If work is carried-out on the motor immediately after it has been operational then there is a danger of burning if hot surfaces are touched.
In order that the motor can cool down close to the level of the intake temperature T_{INTAKE}, the cooling must remain operational for at least 30 minutes after the motor has been powered-down. However, if the cooling is powered-down then it takes a significantly longer time until the motor has cooled down. In this case the mounting arrangement plays a decisive role.

Danger

Danger of burning!

Danger of pressure surges: Do not power-up the cooling if the motor was previously operated without cooling. The steam that is then quickly generated can cause burns and can also destroy the motor.

There is a danger of burns when withdrawing the cooling system as a result of hot cooling water and steam that can be discharged. If the motor is operated without any cooling then the cooling water in the cooling system heats up.

Only connect the cooling after the motor has sufficiently cooled-down.

Warning

The motor insulation can be damaged when using high voltage to check the insulation resistance!
If the insulation resistance has to be checked at a machine/equipment with torque motors or directly at the torque motor (e.g. checking the installation, preventive maintenance, troubleshooting), then only test equipment in compliance with IEC 61557-1, IEC 61557-2 and IEC 61010-1 may be used.
Only a maximum DC voltage of 1000 V over a maximum time of 60 s may be used to make the check! If a higher DC voltage or AC voltage is required to check the machines/equipment, then before carrying-out the check, all of the motor connections must be disconnected.
Carefully observe the Operating Instructions of the test equipment!

When checking the insulation resistance at individual motors only use the following procedure:

(1) Connect all of the winding and temperature sensor connections with one another; check with max. 1000 V DC, 60 s with respect to a PE connection.

(2) Connect all of the temperature sensor connections to PE, connect all o the winding connectors with one another; check with max. 1000 V DC, 60 s with respect to a PE connection.

The insulation resistance must be at least 10 MΩ; if this is not the case then the motor insulation is defective.

Danger

There is a danger of death, severe bodily injury and/or material damage if untrained personnel carry-out inspection, service and repair work.
Ensure that the personnel that are deployed for this purpose have the necessary know-how, skillsets and experience in order to safely carry-out inspection and maintenance work.
All repair work carried-out on the motor should be carried-out by a SIEMENS Service Center. Refer to the following for the addresses of SIEMENS Service Centers http://www.automation.siemens.com/partner/index.asp.

1.3.7 Disposal information and instructions for built-in torque motors

Danger

Death, severe bodily injury and/or material damage will occur if torque motors or rotors are not professionally and correctly disposed.

Torque motors and their components must be correctly and professionally disposed - also refer to the Chapter "Disposal". It is especially important that the rotor is completely de-magnetized!

The manufacturer will accept the direct drives and their components in their original packaging in order to dispose of them in the appropriate way. The party sending in the motor is responsible for the shipping and disposal costs.

2 Torque Motor Selection

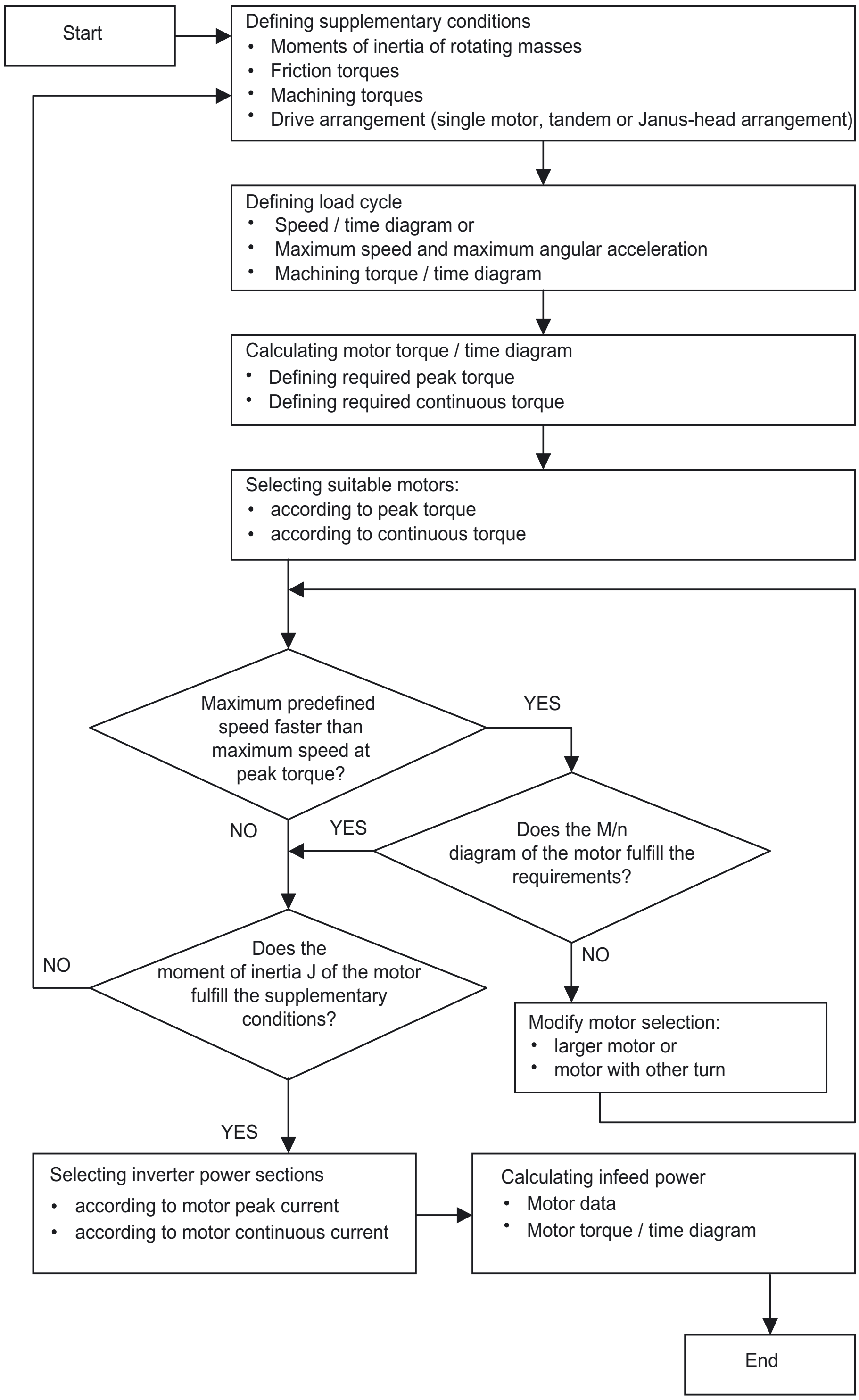
2

2.1 Drive engineering

The selection of a suitable torque motor depends on the following

- the peak torque and continuous torque required for the application
- the required speed and angular acceleration,
- the mounting space available,
- the required or possible drive arrangement
  (single-motor operation or parallel operation),
- the required cooling type.

Generally, the procedure to select a motor is an iterative one. The reason for this is that especially for direct drives with a high dynamic performance, the motor's intrinsic moment of inertia plays a decisive role in the selection process.


Start
Defining supplementary conditions
• Moments of inertia of rotating masses
• Friction torques
• Machining torques
• Drive arrangement (single motor, tandem or Janus-head arrangement)
Defining load cycle
• Speed / time diagram or
• Maximum speed and maximum angular acceleration
• Machining torque / time diagram
Calculating motor torque / time diagram
• Defining required peak torque
• Defining required continuous torque
Selecting suitable motors:
• according to peak torque
• according to continuous torque
Maximum predefined speed faster than maximum speed at peak torque?
YES
NO
Does the M/n diagram of the motor fulfill the requirements?
YES
NO
Modify motor selection:
• larger motor or
• motor with other turn
Does the moment of inertia J of the motor fulfill the supplementary conditions?
NO
YES
Selecting inverter power sections
• according to motor peak current
• according to motor continuous current
Calculating infeed power
• Motor data
• Motor torque / time diagram
End

2.1.1 Mechanical limitations and constraints

Moment of inertia

The kinetic energy of a rotating body is directly proportional to its moment of inertia in [kgm^2]. The moment of inertia takes into account the rotating mass and its spatial distribution over the complete volume of the body with reference to the axis of rotation. The rotating mass comprises the mass of the mechanical assembly to be rotated (e.g. tool and holding mechanism/equipment) and the intrinsic mass of the rotor.

To start, the moment of inertia can be used to approximately identify a suitable motor type.

When continuing to make the calculation, if it appears that there is an excessively high deviation between the initially assumed moment of inertia and the actual moment of inertia, then it will be necessary to make an additional iteration step when selecting the motor.

Frictional torque

Frictional torque M_r opposes the direction of rotation of the rotor. As an approximation, it comprises a constant "Stiction component" M_{RH} and a "Sliding friction component" M_{RG} that is proportional to the speed. Further, both of these components depend on the bearings being used and their load level.

Depending on the type of mechanical design, the loads can include axial forces as well as strain forces between the bearing elements. The data from the bearing manufacturer should be used to calculate the frictional torques.

2.1.2 Entering the load duty cycle

In addition to the frictional torques, the load duty cycle is decisive when selecting a motor. The load duty cycle includes data about the motion sequence of the drive axis and the machining torques that occur.

The motion sequence can be specified as rotary angle/time diagram, angular velocity/time diagram, speed/time diagram or angular acceleration/time diagram. The torques resulting from the motion sequence are proportional to the angular acceleration α and to the moment of inertia J and oppose the acceleration.

$$M_a = J \cdot \alpha$$

Angle/time diagrams and speed/time diagrams can be converted into an angular acceleration/time diagram α(t) using the following equations.

$$\alpha(t) = \frac{dn(t)}{dt} \qquad \alpha(t) = \frac{d^2\varphi(t)}{dt^2}$$

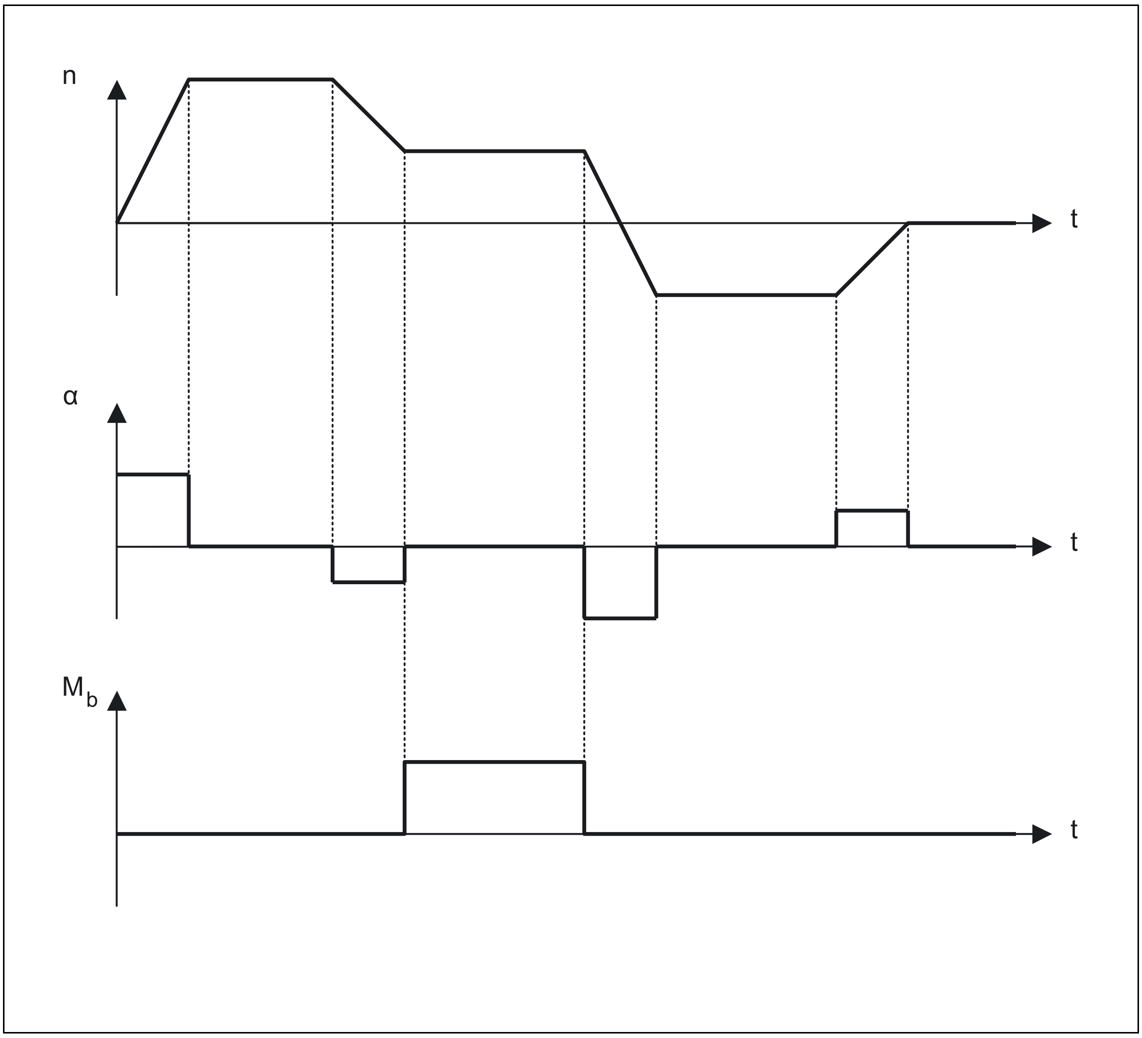


Figure 2-1: Example for a load duty cycle with speed/time diagram, the angular acceleration/time diagram derived from this and the machining torque/time diagram

2.1.3 Torque / time diagram

At any one instant in time, the required motor torque M_m is the sum of the individual torques. It is important to correctly take into account the signs of the torques.

$$M_m = M_a + M_b + M_r$$

The characteristic of the frictional torques over time can be determined based on the speed characteristic. Using the summing formula, the motor torque / time diagram can be generated (refer to the example Figure 2-2); the required peak torque (maximum torque) M_{mMAX} can be directly read from this diagram.

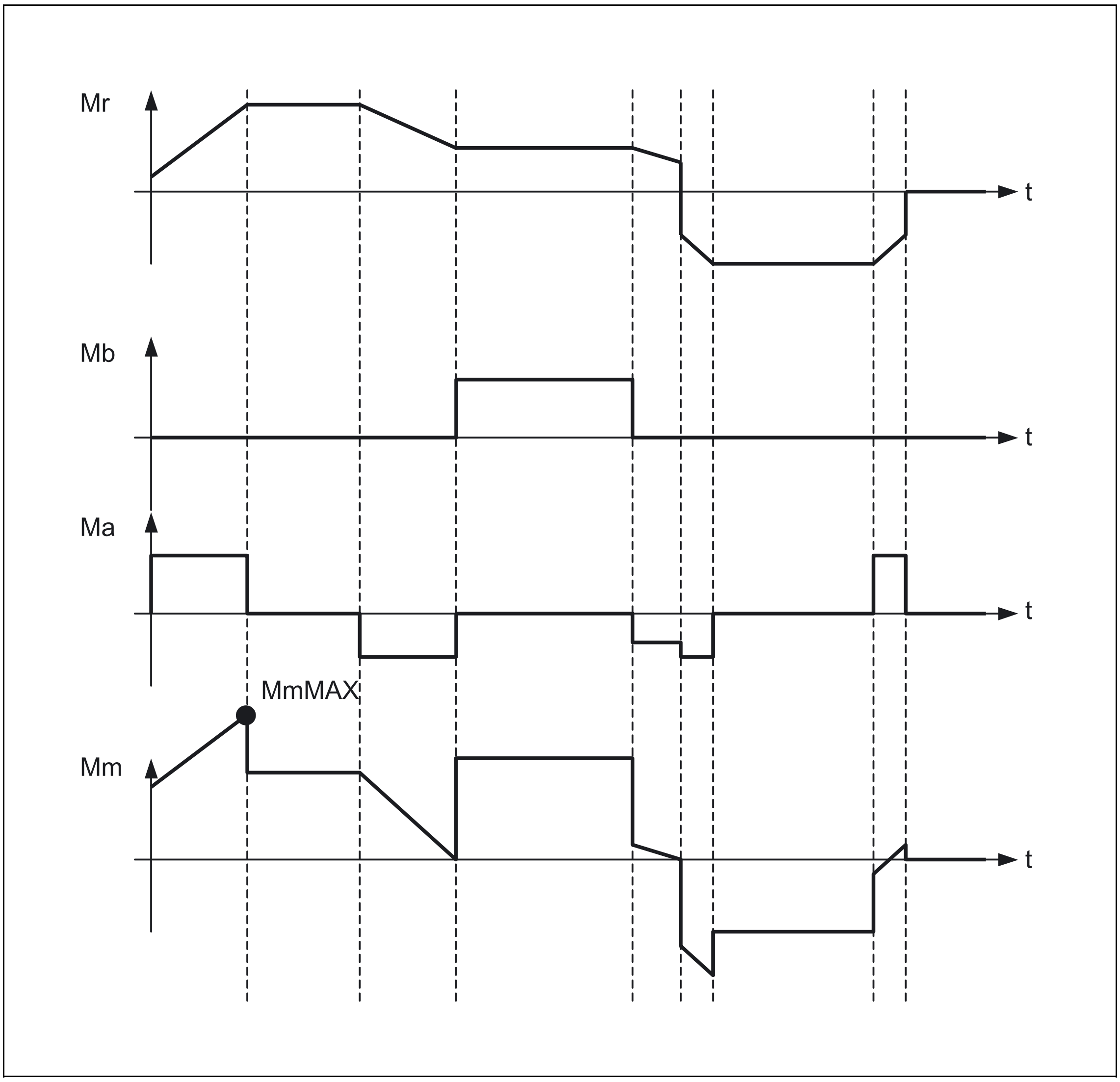


Figure 2-2: Individual torques that occur and the resulting required motor torque M_m for a torque drive as a function of time

In addition to the peak torque, the required continuous motor torque is decisive when dimensioning and selecting the appropriate motor. The continuous torque M_{rms}, that is decisive in determining the motor temperature rise, can be derived from the motor torque / time diagram by forming a root-mean-square value; this may not exceed the rated torque.

$$M_{rms} = \sqrt{\frac{1}{t} \cdot \int_0^t M^2(t)\, dt} \leq M_N$$

If the individual torques are constant on a section-for-section basis, the integral is simplified to become a summing formula (also refer to Figure 2-3).

$$M_{rms} = \sqrt{\frac{M_1^2 \cdot t_1 + M_2^2 \cdot t_2 + M_3^2 \cdot t_3 + M_4^2 \cdot t_4 + \ldots}{t_1 + t_2 + t_3 + t_4 + \ldots}}$$

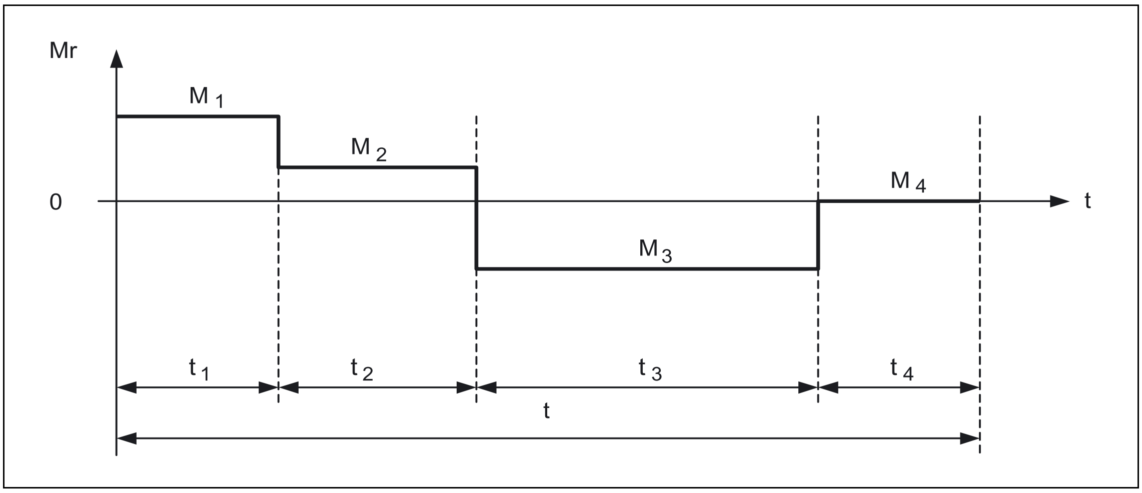


Figure 2-3: Motor torque / time diagram

2.1.4 Selecting the motors

A suitable torque motor can be selected using the values that have been determined for the peak torque M_{mMAX} and the continuous torque M_{rms}. For the peak torque M_{MAX} the following applies: The motor should have about a 10% control margin with respect to the required value M_{mMAX} in order to avoid undesirable limiting effects when control loops overshoot. The continuous torque M_N of the motor must be at least as high as the determined continuous torque M_{rms} of the load duty cycle. If some of the limitations/constraints - such as machining torque and frictional torque - are not known, then it makes sense to include even higher safety margins.

In addition to the requirements from the load duty cycle, mechanical mounting conditions can also influence motor selection. Often, a long motor with smaller diameter as well as a short motor with higher diameter can generate the same motor torques.

If more than one torque motor is involved in generating torque at the axis, the values of the peak and continuous torques of the individual motors must be added.

! **Important**

A uniform current does not flow in all three phases in every motor operating state, e.g.

- at standstill when current flows through the motor, e.g. when
  - equalizing a force due to weight
  - moving against a braking system (damping and shock absorbing elements)
- at low speeds over a longer period of time (n << rpm)
- cyclic rotary motion (distance along the circumference of the rotor < pole width).

If the current flowing through the three phases is not the same over a longer period of time (e.g. permanently), then the motor may only be operated up to approximately 70 % of its rated torque, also refer to M_0* in Chapter "Technical data".

In order to precisely dimension the motor, please contact your local Siemens office.

2.1.5 Motor torque / speed diagrams

At high speeds, the maximum motor torque is limited by the magnitude of the available DC link voltage. If the speeds that occur in the motion sequence are greater than the maximum speed specified for the motor type at the peak torque then it may be necessary to check the motor selection using the motor torque/speed diagrams. This diagram is included with the motor data.

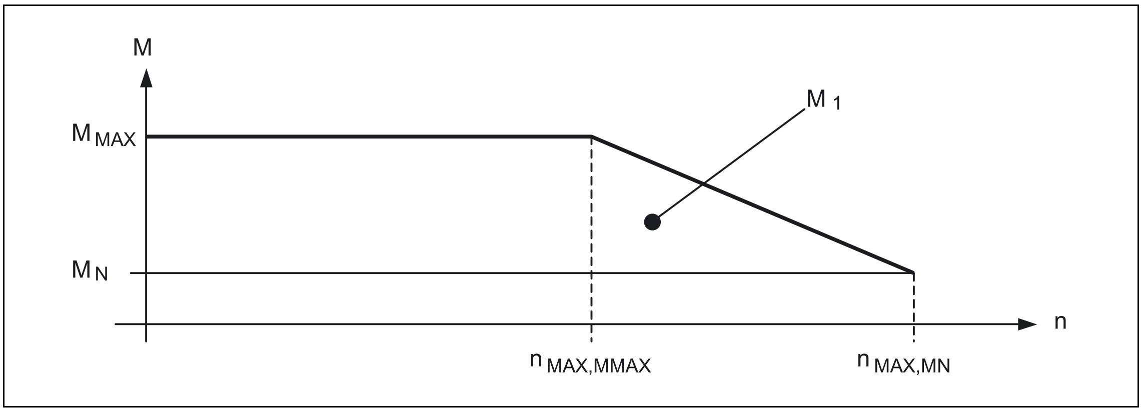


Figure 2-4: Motor torque / speed diagram

If the motor torque/speed diagram is not available, then it can be defined with adequate accuracy from the data for the peak torque M_{MAX}, continuous torque M_N and the associated maximum speeds $n_{MAX,MMAX}$ and $n_{MAX,MN}$ according to Figure 2-4.

This diagram should be compared with the motor torque/time diagram and the speed/time diagram (refer to Figure 2-5. Generally, it is sufficient to select the critical instance in the torque/time diagram where the maximum speed $n_{MAX,MMAX}$ is exceeded at the peak torque. For these instants in time, the motor torque (M_1 in the example) are read-off from the motor torque/time diagram and checked as to whether it lies below the characteristic in the motor torque/speed diagram.

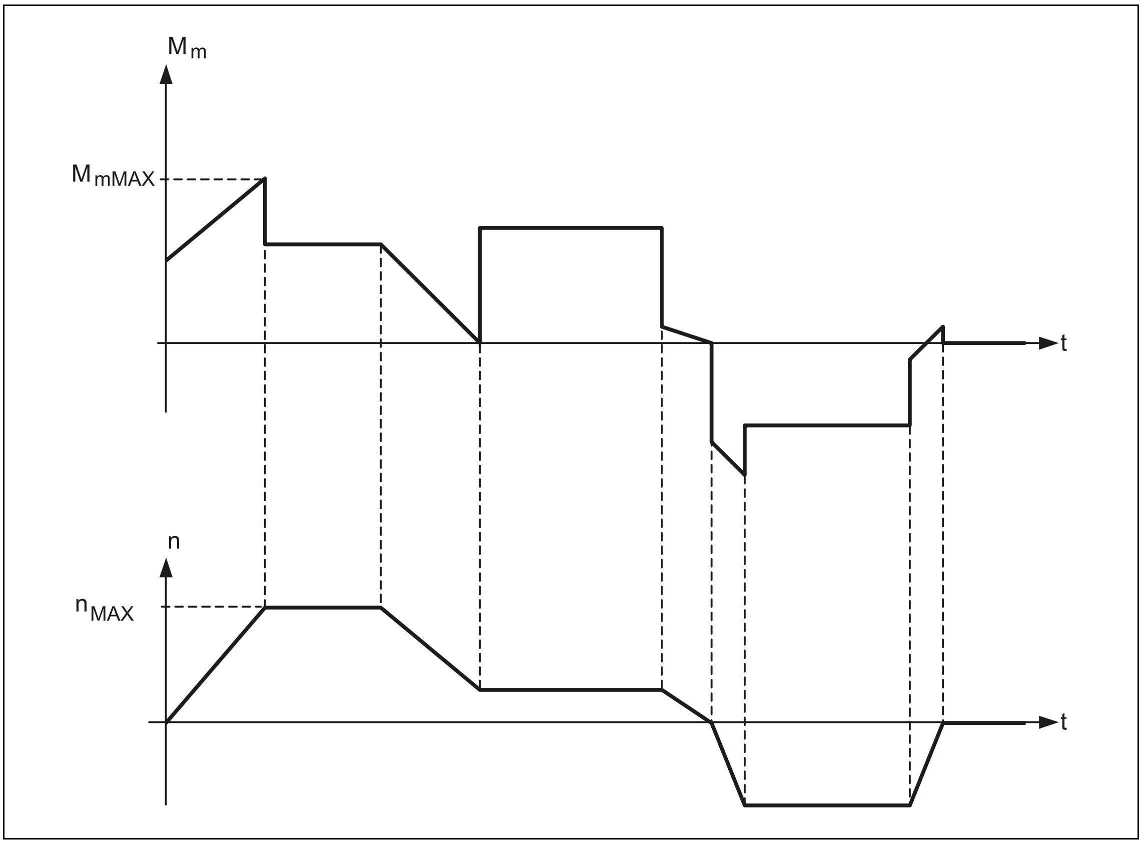


Figure 2-5: Motor torque/time diagram and the corresponding speed/time diagram

If the selected torque motor cannot fulfill the torque/speed requirements, then the following solutions are possible:

- Overspeed
  If there are no high precision specifications in the high speed range (e.g. rapid traverse without machining), then it is permissible to exceed the maximum speed by about 20%. In this case, the drive converter output voltages - and therefore the motor currents - are no longer purely sinusoidal. This means that the torque that the motor generates is no longer uniform but has a certain ripple.

- Torque motor with another winding
  There are already several winding versions for some motor sizes. Windings with a lower number of turns per unit length allow higher speeds with the same motor frame size and maximum torque. However, in this case a higher motor current must be taken into consideration as disadvantage.

- Larger motor type
  If the first two possibilities cannot be implemented then a torque motor with a higher peak torque must be used so that adequate torque margins for the specified torque M_1 are available in the upper speed range (refer to Figure 2-6).

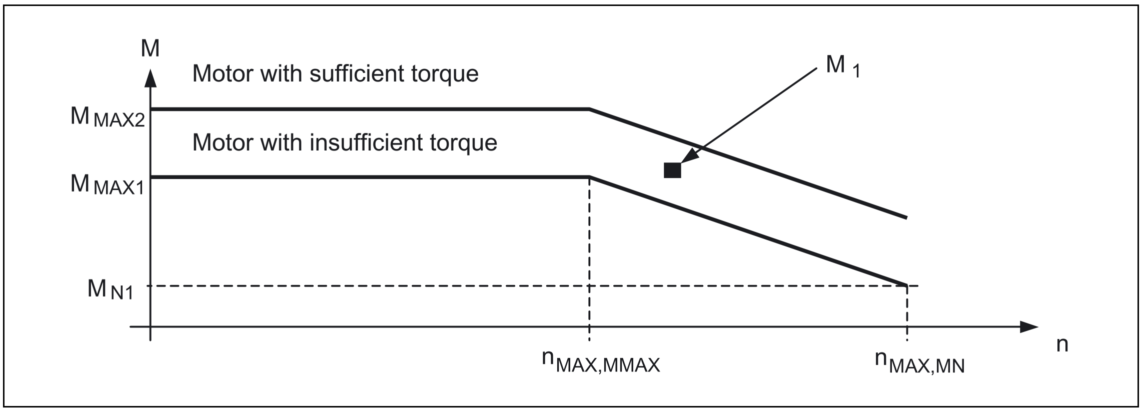


Figure 2-6: Motor torque/speed diagram at the required operating point M_1

2.1.6 Several torque motors connected to one axis

If several torque motors, operated from separate drive converters with separate angular measuring systems are connected to the same axis, then the angular alignment of the individual stators with respect to one another and the individual rotors with respect to one another are of no significance.

However, if the motors are operated from the same drive converter (electrically connected in parallel), the rotors must be mounted on the axis so that they are precisely aligned with one another. Correspondingly, the individual stators must also be mounted so that they are precisely aligned with respect to one another (refer to Chapter "Several motors operated in parallel").

2.1.7 Checking the moments of inertia

After the appropriate torque motor has been selected the moment of inertia of the rotating axis mass must be determined. Using this value, the assumptions made regarding the load duty cycle can be checked. If the initially assumed moments of inertia deviate noticeably from the actual moment of inertia then it maybe necessary to re-calculate the load duty cycle.

2.1.8 Selecting the inverter power units

The power units are selected depending on the peak currents and continuous currents that occur over the completed load duty cycle. If several motors are operated in parallel with one drive converter, then the summed values of the peak and continuous currents must be taken into account.

Note

For systems where direct drives are used together with regulated (closed-loop control) infeeds, electrical oscillations can occur with respect to ground potential. These electrical oscillations are, among other things, influenced by

- the cable lengths
- the size of the infeed/regenerative feedback module
- the number of axes
- the motor size
- the motor winding design
- the type of line supply
- the actual mounting location

These electrical oscillations result in increased voltage stress levels and can damage the main motor insulation!

This is the reason that we recommend an HFD reactor with damping resistor to dampen oscillations. For details refer to the Configuration Manual for drive converters PJU.

2.1.9 Calculating the infeed required

The electrical infeed power of the torque motors can be determined from the mechanical power to be output and the associated electrical losses.

$$P_{EL} = P_{mech} + P_V = M \cdot \omega + 3 \cdot R_{STR}(T) \cdot I_{rms}^2$$

with

$$I_{rms} = \frac{M}{k_T(T)}$$

M is the motor torque in [Nm], ù, the angular velocity in [1/s] and k_T is the torque constant of the motor in [Nm/A], also refer to the Chapter "Explanation of the formula abbreviations".

Speed n in [rpm] can be converted into an angular velocity as follows:

Example to calculate the angular velocity with n = 80 rpm:

$$\omega = \frac{80}{min} \cdot 2\pi \cdot \frac{1min}{60s} = \frac{8{,}38}{s}$$

For a phase resistance R_{PHASE} (T), of the stator, the value at the rated temperature of the motor winding should be used, also refer to the Chapter "Explanation of the formula abbreviations".

This equation can be used at any time over the load duty cycle. When selecting an infeed unit for the DC link for high-speed direct drives it is generally adequate to determine the peak infeed power that occurs in the load duty cycle. The reason for this is that the continuous power drawn is generally significantly lower. The peak infeed power is generally required when accelerating to the maximum speed (refer to operating point M_1 in Figure 2-6).

When operating several axes simultaneously, to select the infeed unit, the infeed powers of the individual axes should be added with the corresponding coincidence factor. Generally, for high-speed drives, the 200 ms peak power value of the infeed units can be used as selection criterium. The reason for this is that acceleration phases are only extremely short.

2.1.10 Engineering examples

Note

The data used here can deviate from the values specified in Chapter "Technical data". However, this does not change the procedure when engineering drive systems.

Positioning in the specified time

The following limitations/secondary conditions apply:

- moment of inertia [kgm^2] J = 5.1 kg m^2
  (moved, cylindrical mass m = 30 kg with an equivalent radius r = 0.583 m; axis of rotation of the moved mass and motor are identical;
  Calculated from $J = \frac{1}{2} \cdot m \cdot r^2$)

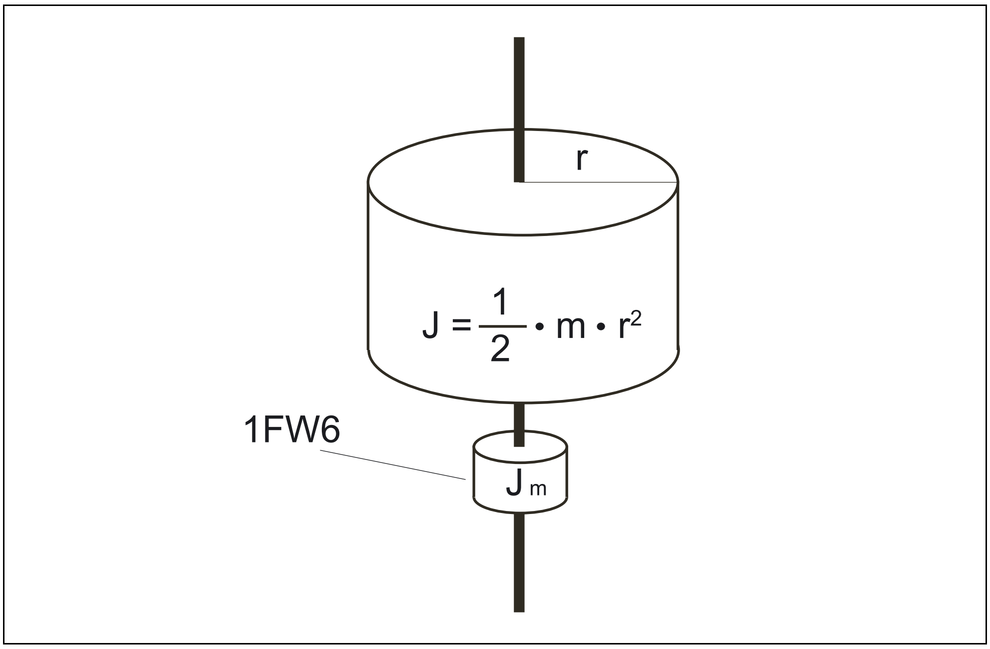


Figure 2-7: Moments of inertia of the moved cylindrical mass and the torque motor

- angle of rotation in [°] or in [rad]: ö = 120° = 2/3 p
- traversing time in [s]: t_1 = 0.4 s
- constant frictional torque in [Nm]: M_r = 100

The following is required:

- the appropriate torque motor
- angular velocity ù in [rad/s] or speed n in [rpm]
- angular acceleration á in [rad/s^2] or acceleration in [rev/s^2]

The traversing profile shape is not specified - instead only the angle that has to be passed through and the time required.

If there are no restricting requirements relating to the angular acceleration and / or angular velocity, the simplest traversing procedure just comprises the acceleration phase followed by the deceleration phase.

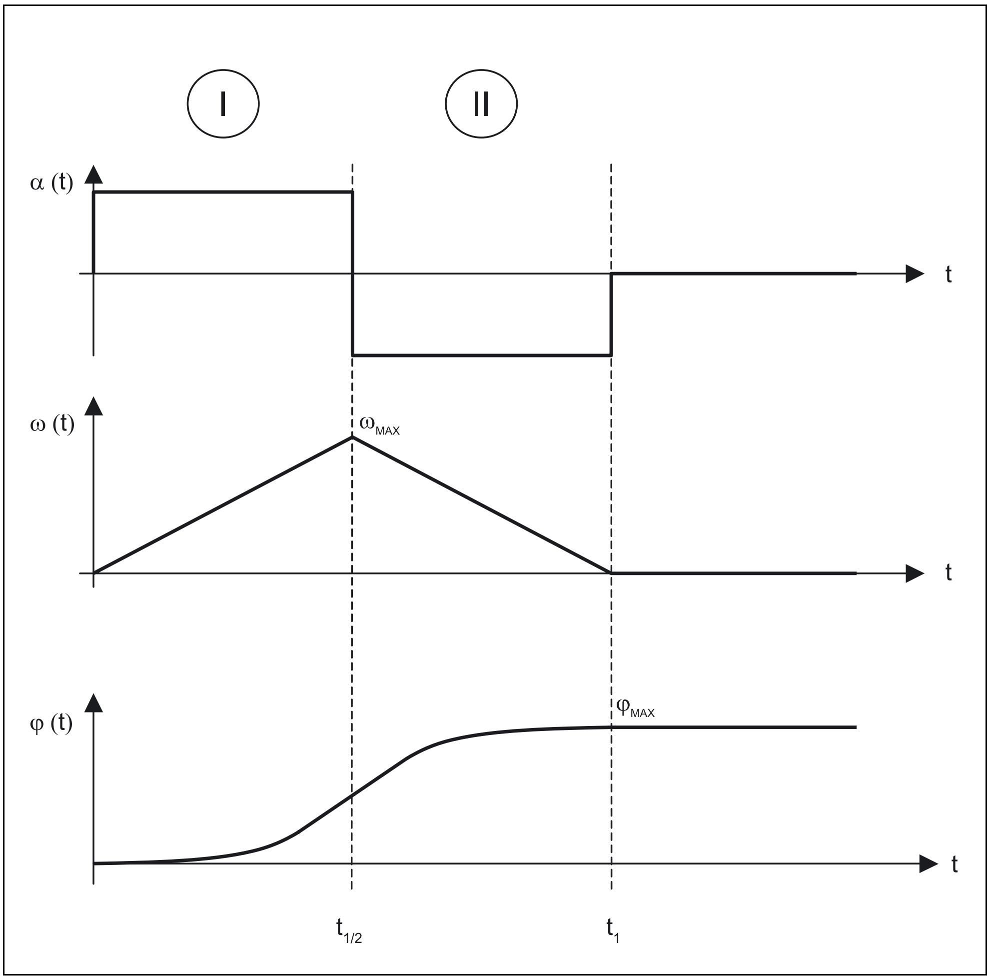


Figure 2-8: An ideal traversing profile: Angular acceleration α (t)
Angular velocity ω (t)
Angle φ (t)

Table 2-1: Functions to the individual sections of the traversing profile

Section I	**Section II**
$\alpha_I (t) = \alpha$	$\alpha_{II} (t) = - \alpha$
$\omega_I (t) = \alpha t$	$\omega_{II} (t) = - \alpha t + \alpha t_1$
$\varphi_I (t) = ½ \alpha t^2$	$\varphi_{II} (t) = - ½ \alpha t^2 + \alpha t_1 t + \varphi_{MAX}$

The angular acceleration α (t) is constant on a section-for-section basis. The angular velocity ω (t) linearly increases in the first section up to the maximum value and then, in the second section linearly decreases down to standstill (zero speed).

The angle of rotation φ (t) passed through increases in section I and section II according to parabolic functions. Such a traversing profile permits the shortest positioning times.

The required constant angular acceleration and angular deceleration can be calculated from the specified (entered) final angle φ_{MAX} and the associated instant t_1. For reasons of simplicity, short transition phases to establish and reduce acceleration rates with the angular jerk that occurs have not been taken into account.

The following applies because in the two sections of this example, the areas under the curves of ω (t) are the same:

$$\varphi_{MAX} = 2 \cdot \left[\frac{\alpha}{2} \cdot \left(\frac{t_1}{2} \right)^2 \right] \quad \text{in [°] or in [rad]} \quad \alpha = \frac{4 \cdot \varphi_1}{(t_1)^2} \quad \text{in [rad/s}^2\text{]}$$

The angular velocity ù$_{MAX}$, reached at the instant in time $t_{1/2}$ is determined from the calculated angular acceleration:

$$\omega_{MAX} = \alpha \frac{t_1}{2} \quad \text{in [rad/s]}$$

The speed n can be calculated from $n = \frac{\omega_{MAX}}{2\pi}$.

Note: 1 rad corresponds to 180°/ π = 57.296 °
1 revolution U corresponds to 360° or 2 π rad

With the specified values, the following is obtained.
Angular acceleration α = 52.36 rad/s^2
Angular velocity ω_{MAX} = 10.47 rad/s
Speed n = 100 rpm

The following applies for the required accelerating torque:

$$M_a = (J + J_m) \cdot \alpha$$

The moment of inertia J_m for the 1FW6 motor is still not known at this phase. This is the reason that initially J_m must be assumed to be 0 kgm^2.

$$M_a = 5{,}1\,\text{kg m}^2 \cdot 52{,}36\,\text{rad/s}^2 = 267\,\text{Nm}$$

A torque M_a of 267 Nm is required to accelerate the specified mass.

$M_m = M_r + M_a$

M_m = 100 Nm + 267 Nm = 367 Nm

Together with the constant frictional torque M_r, a motor torque M_m = 367 Nm is obtained.

A suitable motor is selected from the table "Overview of built-in torque motors" according to the following criteria:

Maximum torque is at least 367 Nm.
The maximum speed (when providing the maximum torque) is at least 100 rpm.

Suitable motors are:
1FW6090-0PA15-2JC2 (diameter 230 mm, length 190 mm)
1FW6130-0PA05-1JC2 (diameter 310 mm, length 90 mm)

The moment of inertia of the motor 1FW6090-0PA15-2JC2 is J = 0.0465 kgm^2.

Accelerating torque M_a can now be corrected to:

$$M_a = (5{,}1\,kg\,m^2 + 0{,}0465\,kg\,m^2) \cdot 52{,}36\,rad/s^2 = 269\,Nm$$

This means that the total required motor torque $M_m = M_r + M_a$ increases to 369 Nm.

The moment of inertia of motor 1FW6130-0PA05-1JC2 is J = 0.0637 kgm^2.

The accelerating torque M_a can now be corrected to:

$$M_a = (5{,}1\,kg\,m^2 + 0{,}0637\,kg\,m^2) \cdot 52{,}36\,rad/s^2 = 270\,Nm$$

This means that the total required motor torque $M_m = M_r + M_a$ increases to 370 Nm.

Assessment:
Both motors are suitable for this positioning task. The requirements from the mounting arrangement will decide which motor is the best choice. While positioning, the motor develops a torque higher than its rated torque M_N and the power loss that occurs is far higher than the permissible continuous power loss. If the positioning operation only takes a short time and the winding temperature rise remains below the shutdown (trip) limit, then the high load level is permissible. Also refer to Chapter "Intermittent duty S3"

Repeated periodic load duty cycle (S3 duty)

The motor can repeat a particular drive operation (e.g. the positioning operation described above) where temporarily $M > M_N$ occurs for an unlimited time if there are sufficiently long intervals where the windings are in a no-current condition between the load phases. Also refer to Chapter "Intermittent duty S3"

The load phase and the no-current (cooling-down) phase are combined under the term "Load duty cycle". In this case, the cooling-down phases are very important: As a result of the no-load intervals, the rms torque of the load duty cycle is reduced to the value of the rated torque M_N of the motor.

If the future load duty cycle is neither known nor can it be estimated, then the motor can only be selected according to the required maximum speed and the required maximum torque. Therefore, the maximum permissible continuous torque is defined for the load duty cycle. This results in a minimum possible cooling-down phase – the duration of which may not be fallen below.

As an example, a significantly simplified load duty cycle is assumed comprising three time sections, lengths t_1, t_2, t_3. Torques M_1, M_2, M_3 are provided in these time sections. Each of these torques can have any value between + M_{MAX} and – M_{MAX}. The rms torque M_{rms} of this load duty cycle can then be calculated in [Nm] using the following formula:

$$M_{rms} = \sqrt{\frac{M_1^2 \cdot t_1 + M_2^2 \cdot t_2 + M_3^2 \cdot t_3}{t_1 + t_2 + t_3}}$$

In this case the duty cycle duration (t_1 + t_2 + t_3) should not exceed 10 % of the thermal time constant t_{TH}.

The load duty cycle is permissible as long as $M_{rms} \leq M_N$.

3 Built-in Torque Motors 3

3.1 Features and motor components

Use and applications

1FW6 torque motors have been designed as built-in motors for use in slow direct drives providing high torques. The liquid cooling allows them to fulfill high demands regarding the thermal behavior within the machine assembly.

In conjunction with the SIMODRIVE 611 digital/universal HR converter system, the built-torque motors can be used as direct drive for the following machine applications:

- rotary indexing machines, rotary tables, swiveling axes
- rotary axes (A, B, C axis in 5-axis machine tools)
- rotary table, rotary index table, sub-machine sections
- turret indexing and cylinder indexing for single-spindle and multi-spindle machines
- dynamic tool magazines
- rotating spindles in milling machines
- roll and cylinder drives
- feed and handling axes

Warning

The motors are not designed to be connected directly to the line supply. They may only be fed from drive converter systems.

Note

Please note that when 1FW6 direct motors (torque motors) are used in fork heads for machine tools or robots, a license for US patent US5584621 and the associated international trademark may be required.

Features

Built-in torque motors are liquid-cooled, slow-speed (high pole number), permanent-magnet three-phase synchronous motors with hollow-shaft rotors. The motors are supplied as built-in components that are kept together when shipped using a transport security device (refer to Figure 3-2 und Figure 3-3). For a complete drive unit bearings and shaft encoder are also required.

Presently, the range of motors comprises 6 frame sizes (or outer diameters) each with 4 axis lengths. Every motor is available for at least two different speed ranges. (Exception: Presently, 1FW6290 can only be ordered in one axis length and with one speed range). The stator and the rotor have flanges at both ends with centering surfaces and tapped holes which allow them to be integrated into a machine.

The motors distinguish themselves as follows:

- extremely high power density
- high torque with a compact design and low envelope dimensions
- wide range of types
- high overload capability (factor 1.6 ... 2.2) - the current drain of the windings is adapted to the SIMODRIVE drive converter power ratings
- low moment of inertia
- high degree of availability as there are no gearbox components in the mechanical drive transmission line which are subject to wear
- water cooling to increase the rated power
- directly flanged to the machine
- cable outlet, axial, radial outer or tangential for all frame sizes

Standards, regulations

The motors are developed and designed taking into account the relevant standards and regulations applicable at this time.

Technical features

The motors that must be fed from drive converters are designed for operation on a 600 V DC link voltage level (preferred value) and require an impressed sinusoidal current. The SIMODRIVE 611 drive converter system is dimensioned to be directly connected to TN line supplies. The permissible rated voltages of TN line supplies as listed in Table "Permissible rated voltages of TN line supplies for torque motors, resulting DC link voltages and drive converter output voltages" in the Chapter "System prerequisites" apply to torque motors.

The DC link voltage level depends on the line supply voltage and can be greater than 600 V.

Matching transformers, tailor-made for the system are available to adapt the system for use with other line supply types, such as for operation on IT or TT line supplies.

Table 3-1: Standard version of 1FW6 torque motor

Technical feature	Type
Motor type	Synchronous motor with permanent-magnet rotor multi-pole (number of rotor poles from 44 to 98)
Type of construction	Individual components: Stator, rotor
Degree of protection acc. to IEC 60034-5	Motor : IP23 The final degree of protection (minimum degree of protection: IP54) of the installed motor is defined by the machinery construction company (OEM). Protection against coming into contact, foreign bodies and water for electrical equipment is specified in accordance with IEC 60034-5.
Cooling method	Liquid cooling: – Jacket cooling, frame sizes 1FW6090, 1FW6130 – Integrated cooling, frame sizes 1FW6160, 1FW6190, 1FW6230, 1FW6290
Materials used in the cooling circuit	Max. 10 bar (steady-state)
Cooler connection	Motors with cooling jacket – The connection must be made on the customers side Motors with integrated cooling – Connection with / without cooling connection adapter Refer to Chapter "Motor installation"
Temperature monitoring	2 x PTC thermistor triplet with a response threshold +130 /150 °C (acc. to DIN 44081/44082) and 1 x KTY84 PTC thermistor (acc. to IEC 60034-11) in the stator
Insulation of the stator winding EN 60034-1 (IEC 60034-1)	Temperature class F
Magnet material	Rare-earth material
Connection, electrical	Cable outlet, axial, radial outer or tangential; Standard: Cables (l=2 m) with free cable ends are used to connect the power and sensors
Motor feeder cables	Refer to Chapter "Interfaces" for the specification of the motor feeder cables
Torque ripple	≤ 1.5 % M_0

Note

The specified values in Table 3-1 are only valid in conjunction with the system prerequisites described in the Chapter "System integration".

Direction of rotation

The direction of rotation of the rotor of the built-in motor is clockwise. This can be seen when viewing the motor from the drive side.

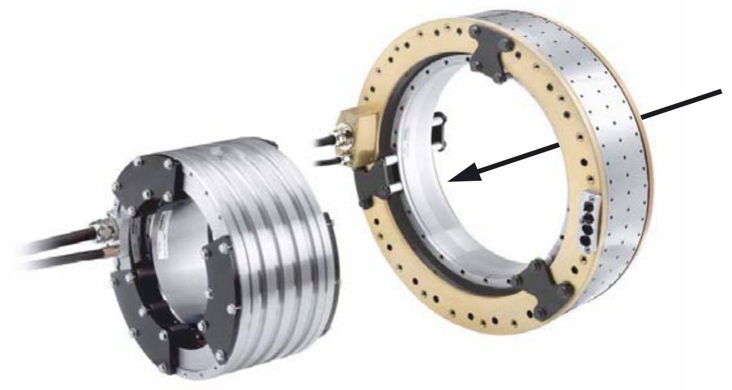


Figure 3-1: Viewing direction to determine the direction of rotation

Motor components

The built-in torque motor consists of the following components:

- Stator - this comprises an iron core and a 3-phase winding.
  The winding is cast in order to better dissipate the heat losses; the motor is designed for liquid cooling (main cooler). The cooling is designed differently for the different frame sizes (outer diameter).

- Rotor - this is the reaction part of the motor. It comprises a cylindrical hollow steel shaft that has permanent magnets around its circumference.

- Cooling connection adapter (option) - if the main and precision cooler are operated in parallel on one cooler, a cooling connection adapter can be ordered.

Note

An additional motor rating plate is supplied with the motor so that the customer can decide where this should be located. If the motor rating plate is removed then it must be made unusable.
If the stator and rotor are subsequently separated from one another then it must be ensured that they can be subsequently matched-up with one another again.

Motors with cooling jacket

The surface of the motor cooling jacket comprises ring-type grooves that form a closed liquid cooling circuit with the appropriate surrounding mechanical assembly, prepared by the machinery construction OEM.

The machinery construction OEM must provide the intake and outlet for the cooling medium at the surrounding mechanical assembly.

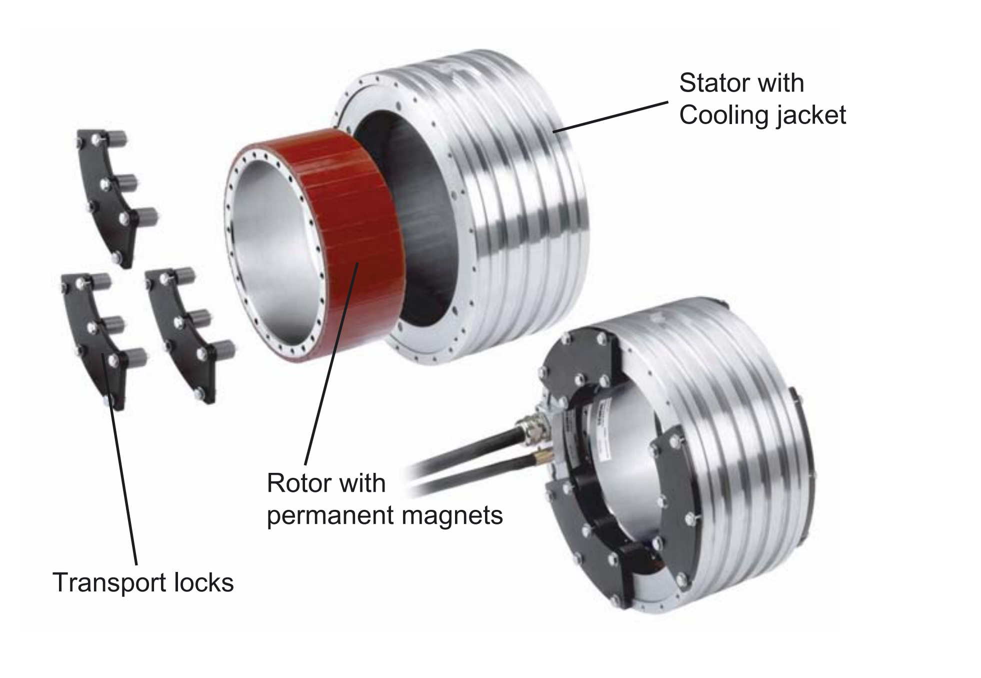


Figure 3-2: 1FW6 motor components with cooling jacket

Scope of supply of the built-in torque motors with cooling jacket:

1. The rotor is held in the stator using transport locks and a foil to maintain the appropriate clearance
2. The stator with cooling jacket and cables with free cable ends for the power and signal connections
3. Transport locks with distance elements and bolts
4. O-rings (number: 2)
5. Motor rating plate, glued on; additional motor rating plate supplied loose
6. Safety information and instructions

Motors with integrated cooling

These motors have an integrated dual-circuit cooling system that is ready to be connected-up. This means that they are essentially thermally insulated with respect to the mechanical axis assembly.

The two-circuit cooling system comprises a main and precision cooler (according to the Thermo-Sandwich® principle).

A high proportion of the winding losses P_v of the stator is dissipated using an inner cooling circuit (main cooler). A thermal insulating layer - located between the iron core and the mounting flange of the stator - prevents heat from being conducted from the motor winding to the mechanical assembly.

The heat (thermal energy) that still flows through this insulating layer is to a large extent absorbed and dissipated by a second thermal sink (precision cooler) at the flange surfaces. This means that a constant, low temperature is achieved at the mounting surfaces of the stator under all of the permissible operating conditions.

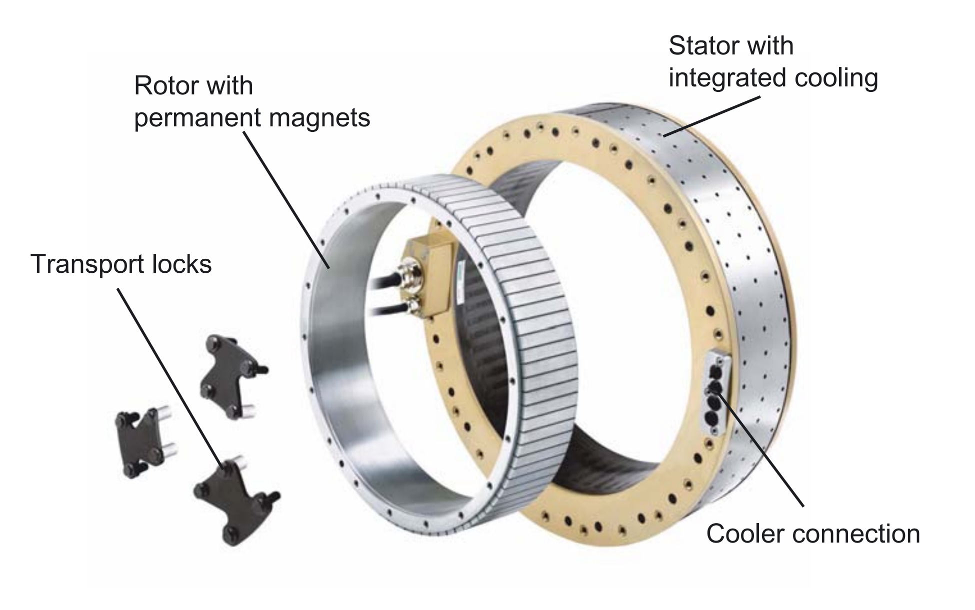


Figure 3-3: 1FW6 motor components with integrated cooling

Scope of supply of the built-in torque motors with integrated cooling:

1. The rotor is held in the stator using transport locks and a foil to maintain the appropriate clearance
2. The stator with ready-to-connect two-circuit cooling and cables with free cable ends for the power and signal connections
3. Transport locks with distance elements and bolts
4. Motor rating plate, glued on; additional motor rating plate supplied loose
5. Safety information and instructions

Cooling versions

The stators of built-in torque motors have a liquid cooler to dissipate the power losses.

The cooling system design depends on the size (outer diameter) of the motor, refer to Table 3-2.

Table 3-2 Cooling system design

Size	Cooling jacket	Integrated cooling
1FW6090	X	
1FW6130	X	
1FW6160		X
1FW6190		X
1FW6230		X
1FW6290		X

3.2 Motor rating plate and order designation

Motor rating plate

The motor rating plate shown below is an example. The data only apply in conjunction with the associated rotor.

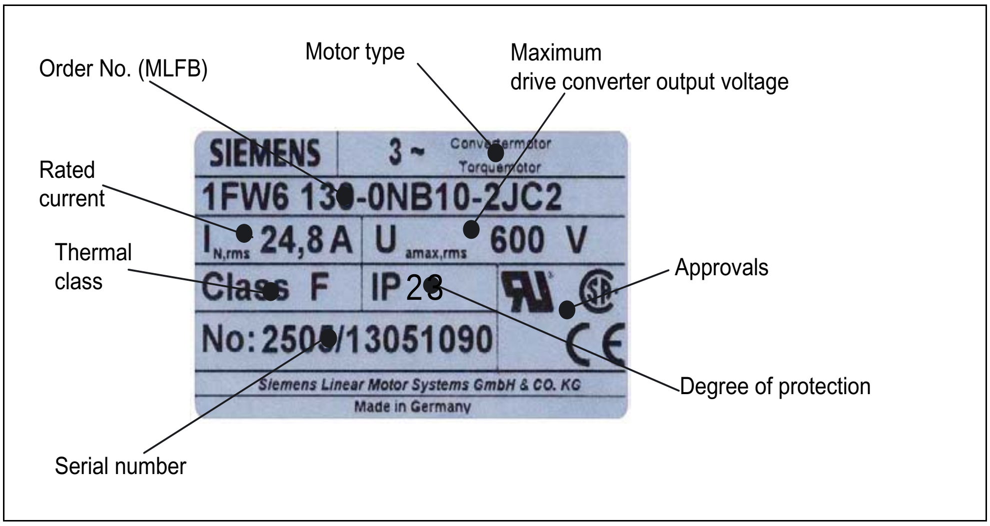


Figure 3-4: Motor rating plate for 1FW6 built-in torque motors

Ordering information

The complete built-in motor (stator, rotor with transport locks) can be ordered using a single Order No. (MLFB). Spare parts and accessories can be ordered with their own Order Nos. (refer to the ordering example).

The MOTION–CONNECT cable, that is required to connect to the drive converter is not included with the motors and must be separately ordered, refer to SIMODRIVE drive converters /PJU/, Chapter 10.1 and Catalog NC 60.

Note

If, for mechanical design reasons, only individual components (stator and rotor separate) can be installed, then these can be separately ordered and shipped.

Warning

Assembly equipment must be provided on the customer side when separately installing and mounting stators and rotors; the reason for this is the high forces of attraction of the rotor.
Support from your local Siemens office is absolutely necessary when handling individual components.

Structure of the Order No.

The Order No. (MLFB) comprises a combination of digits and letters. It is sub-divided into three hyphenated blocks. Also refer to Figure 3-5 ff.

The first block has 7 positions and designates the motor type (1FW6) and the length of the stator (in mm). Additional features are coded in the second and third blocks.

Please note that not every theoretical combination is possible.

Ordering examples

Example 1:

Stator and rotor pre-assembled with transport locks; outer cooling jacket; axial cable outlet for SIMODRIVE 611 digital/universal HR drive converters, 18/36 A power unit:

Order No. [MLFB] 1FW6090–0PB15–1JC2 (stator, rotor, transport locks)

Example 2:

Stator and rotor pre-assembled with transport locks; integrated cooling; radial cable outlet towards the outside, for SIMODRIVE 611 digital/universal HR drive converters, 18/36 A power unit:

Order No. [MLFB] 1FW6190–0VB07–1JC2 (stator, rotor, transport locks)

Example 3:

Axial/radial cooling connection adapter for frame sizes 1FW6160, 1FW6190 and 1FW6230:

Order No. [MLFB] 1FW6160–1BA00–0AA0 (cooling connection adapter)

Example 4, individual components and spare parts:

Replacement stator:	Order No. 1FW6190–**8V**B07–1JC2
Spare rotor:	Order No. 1FW6190–**8R**A07–0AA0
Spare O-ring*) (for frame size 1FW6090)	Order No. 1FW6090–**1E**A00–0AA0

*) presently this can only be directly ordered from the motor manufacturer

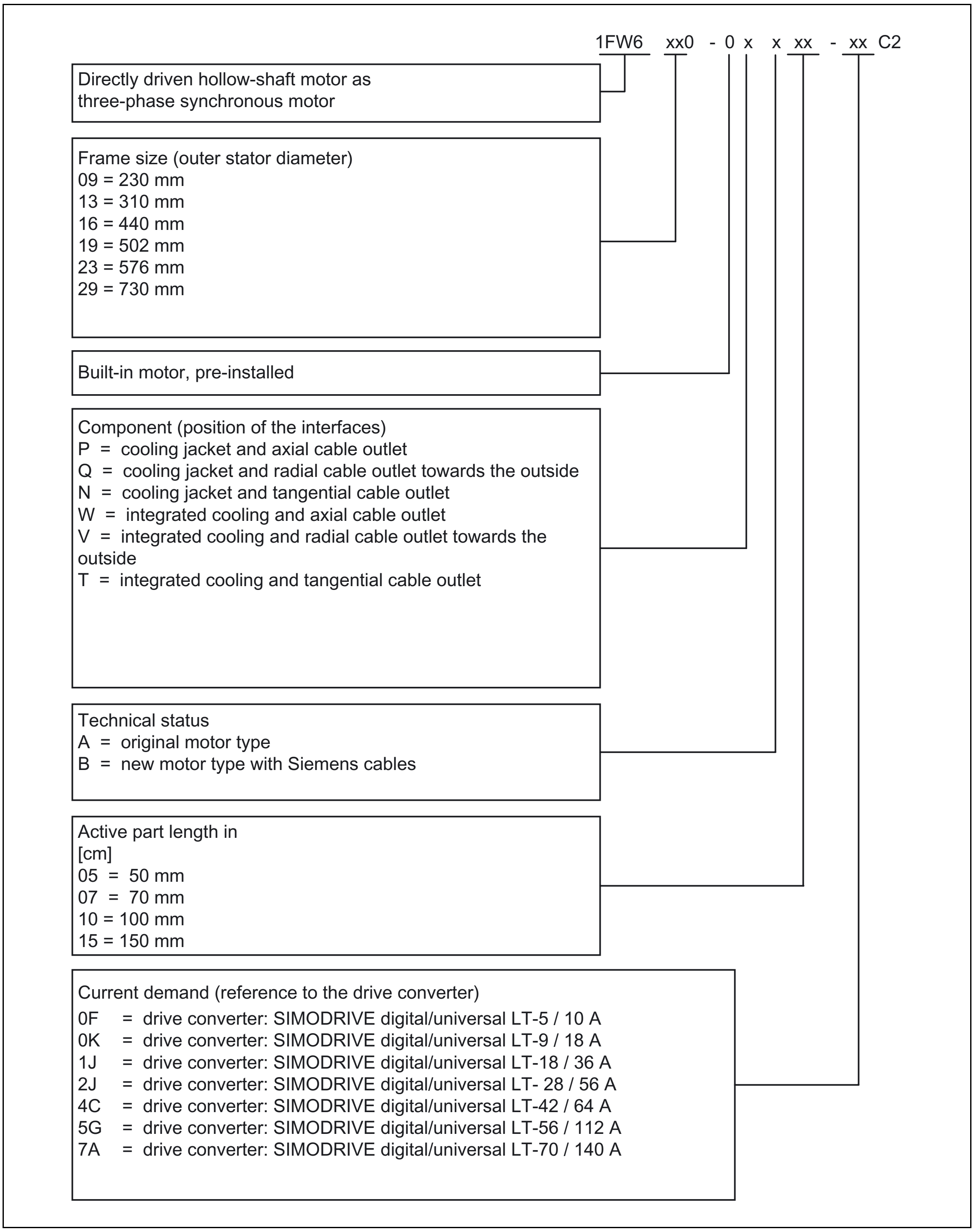


Figure 3-5: Order No., standard 1FW6 built-in torque motor

Note

The cable outlet cannot be subsequently modified. This is the reason that when ordering the motor it must be ensured that the correct Order No. (MLFB) is specified.

The cooling connection adapter is not included with the standard version of the built-in motor. Separate Order No., refer to Figure 3-9.

When selecting a motor type (type A or B) note the Tables "Data of the motor feeder cables" in Chapter "Interfaces".

1FW6 xx0 - 8 x x xx - xx C2

Directly driven hollow-shaft motor as three-phase synchronous motor

Frame size (outer stator diameter)
09 = 230 mm
13 = 310 mm
16 = 440 mm
19 = 502 mm
23 = 576 mm
29 = 730 mm

Individual components

Component (position of the interfaces)
P = cooling jacket and axial cable outlet
Q = cooling jacket and radial cable outlet towards the outside
N = cooling jacket and tangential cable outlet
W = integrated cooling and axial cable outlet
V = integrated cooling and radial cable outlet towards the outside
T = integrated cooling and tangential cable outlet

Technical status
A = original motor type
B = new motor type with Siemens cables

Active part length in [cm]
05 = 50 mm
07 = 70 mm
10 = 100 mm
15 = 150 mm

Current demand (reference to the drive converter)
0F = drive converter: SIMODRIVE digital/universal LT-5 / 10 A
0K = drive converter: SIMODRIVE digital/universal LT-9 / 18 A
1J = drive converter: SIMODRIVE digital/universal LT-18 / 36 A
2J = drive converter: SIMODRIVE digital/universal LT- 28 / 56 A
4C = drive converter: SIMODRIVE digital/universal LT-42 / 64 A
5G = drive converter: SIMODRIVE digital/universal LT-56 / 112 A
7A = drive converter: SIMODRIVE digital/universal LT-70 / 140 A

Figure 3-6: Order No. of a stator as individual component

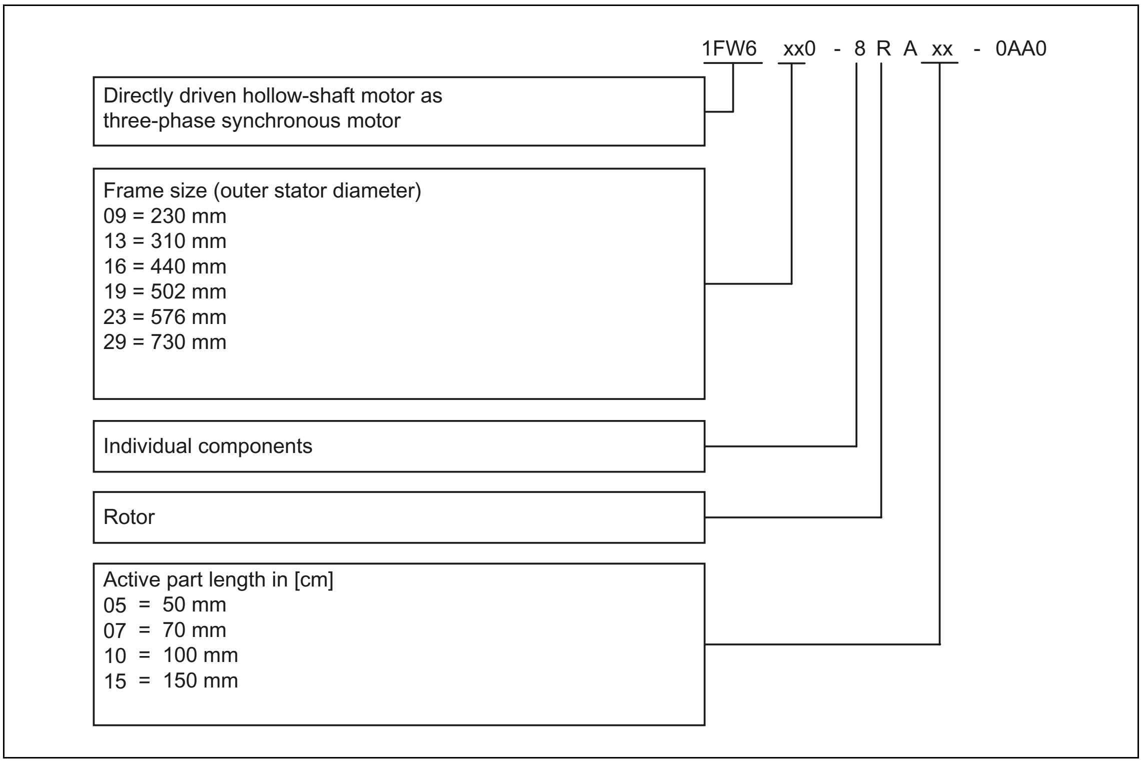


Figure 3-7: Order No. of a stator as individual component

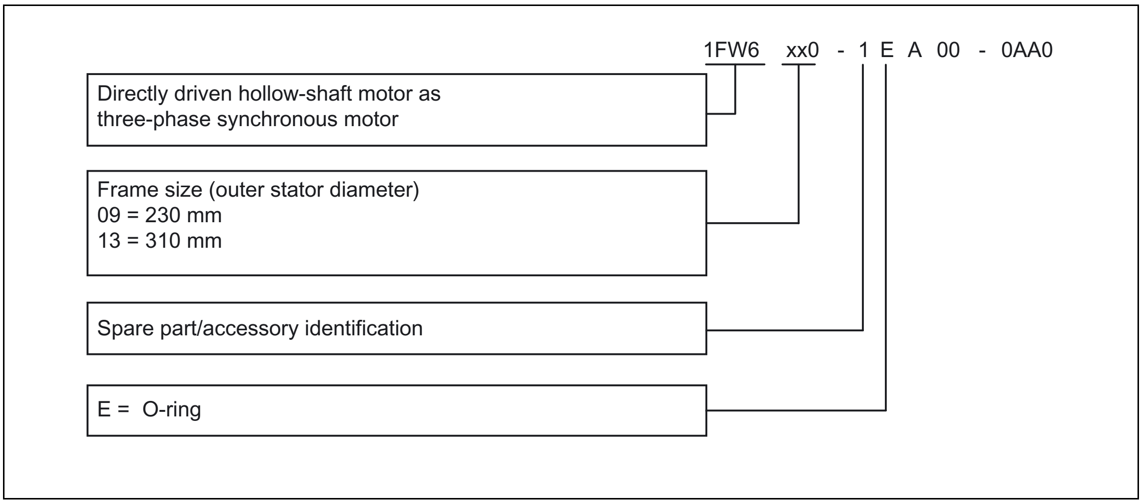


Figure 3-8: Order No. of an O-ring *)

*) presently this can only be directly ordered from the motor manufacturer

1FW6 xx0 - 1 B A 00 - 0AA0

Directly driven hollow-shaft motor as three-phase synchronous motor

16 = Cooling connection adapter fits frame sizes 16, 19 and 23

29 = Cooling connection adapter fits frame size 29

Spare part/accessory identification

B = Cooling connection adapter for built-in motor with integrated cooling (not available for frame sizes 09 and 13, as these are the motors with cooling jacket); combination connection for the main and precision cooling (internally connected) axial and radial towards the outside.
This is an option, please order when required.

Figure 3-9: Order No., cooling connection adapter

3.3 CSA/UL certification

Type B torque motors are listed (certified) by the Canadian Standards Association (CSA) and the Underwriters Laboratories Inc. (UL). Also refer to the Table "Motor types that can be ordered " in Chapter "Interfaces".

In order that the certification is valid, the following must be carefully observed when operating the motors:

- The limit data specified in Chapter "Technical data" may not be exceeded.
- The motor must be operated with water cooling using its cooling system. Also refer to the Chapter "Cooling"
- The intake temperature according to Chapter "Technical data" may not be exceeded.
- The power cable may not be hotter than 80 °C.

Table 3-3: Symbol on the motor rating plate

	Built-in torque motors
	Stator (individual)

3.4 System integration

3.4.1 System prerequisites

The motors that must be fed from drive converters are designed for operation on a 600 V DC link voltage level (preferred value) and require an impressed sinusoidal current. The SIMODRIVE 611 drive converter system is dimensioned to be directly connected to TN line supplies. The permissible rated voltages of TN line supplies as listed in following Table.

The DC link voltage level depends on the line supply voltage and can be greater than 600 V.

Matching transformers, tailor-made for the system are available to adapt the system for use with other line supply types, such as for operation on IT or TT line supplies.

Table 3-4: Permissible rated voltages of TN line supplies for the SIMODRIVE 611 drive converter system - resulting DC link voltages and drive converter output voltages

Permissible line supply voltage	**Resulting DC link voltage $V_{DC\ link}$**	**Drive converter output voltage (rms value) V_{amax}**
400 V	600 V (regulated) 540 V (non-regulated)	425 V (regulated) 380 V (non-regulated)
480 V	648 V (non-regulated)	460 V (non-regulated)

SINUMERIK/SIMODRIVE fulfills the prerequisites for operation under the following conditions:

- SIMODRIVE 611 digital with Performance and High-Performance or High-Standard control modules in conjunction with SINUMERIK 840 D or SINUMERIK 810D
- SIMODRIVE 611 universal or SIMODRIVE 611 universal HR
- SINUMERIK 810D CCU-3
- The power unit selected depends on the motor current at torque M_0 and a speed rpm or according to the maximum current of the motor
- Built-in torque motors should be set-up as **S**ynchronous **R**otating **M**otor (SRM)
- The encoder system being used must be suitable for the particular application

Note

For systems where direct drives are used together with regulated (closed-loop control) infeed units, electrical oscillations can occur with respect to ground potential. These oscillations are, among other things, influenced by

- the cable lengths
- the size of the infeed/regenerative feedback module
- the number of axes
- the motor size
- the motor winding design
- the type of line supply
- the actual mounting location

These electrical oscillations result in increased voltage stress levels and can damage the main motor insulation!

This is the reason that we recommend that an HFD reactor with damping resistor is used to dampen the oscillations. For details refer to the Configuration Manual for drive converters PJU.

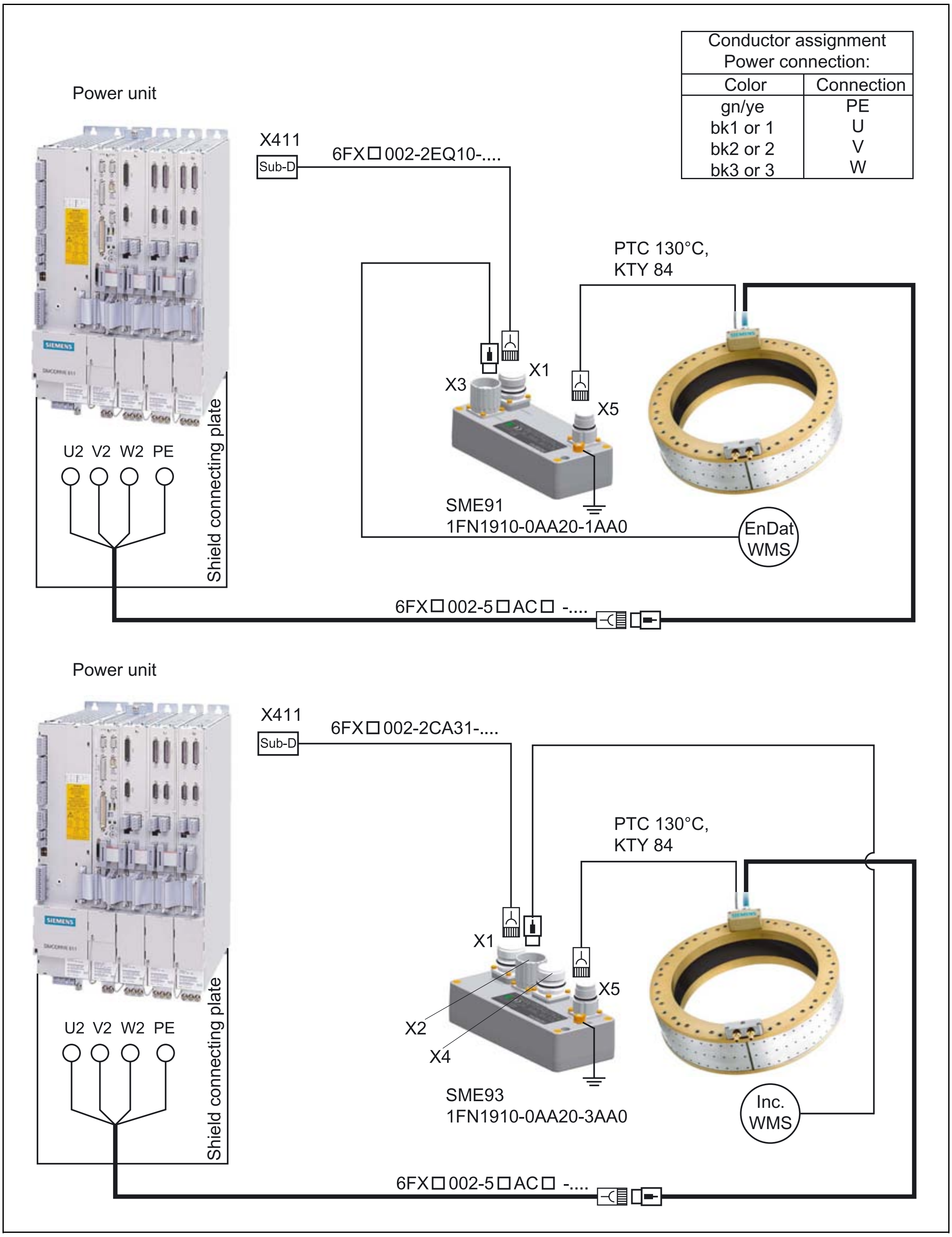


Figure 3-10: System integration with connection of the PTC 130 °C and KTY 84 via SME9x; WMS: EnDat or incremental

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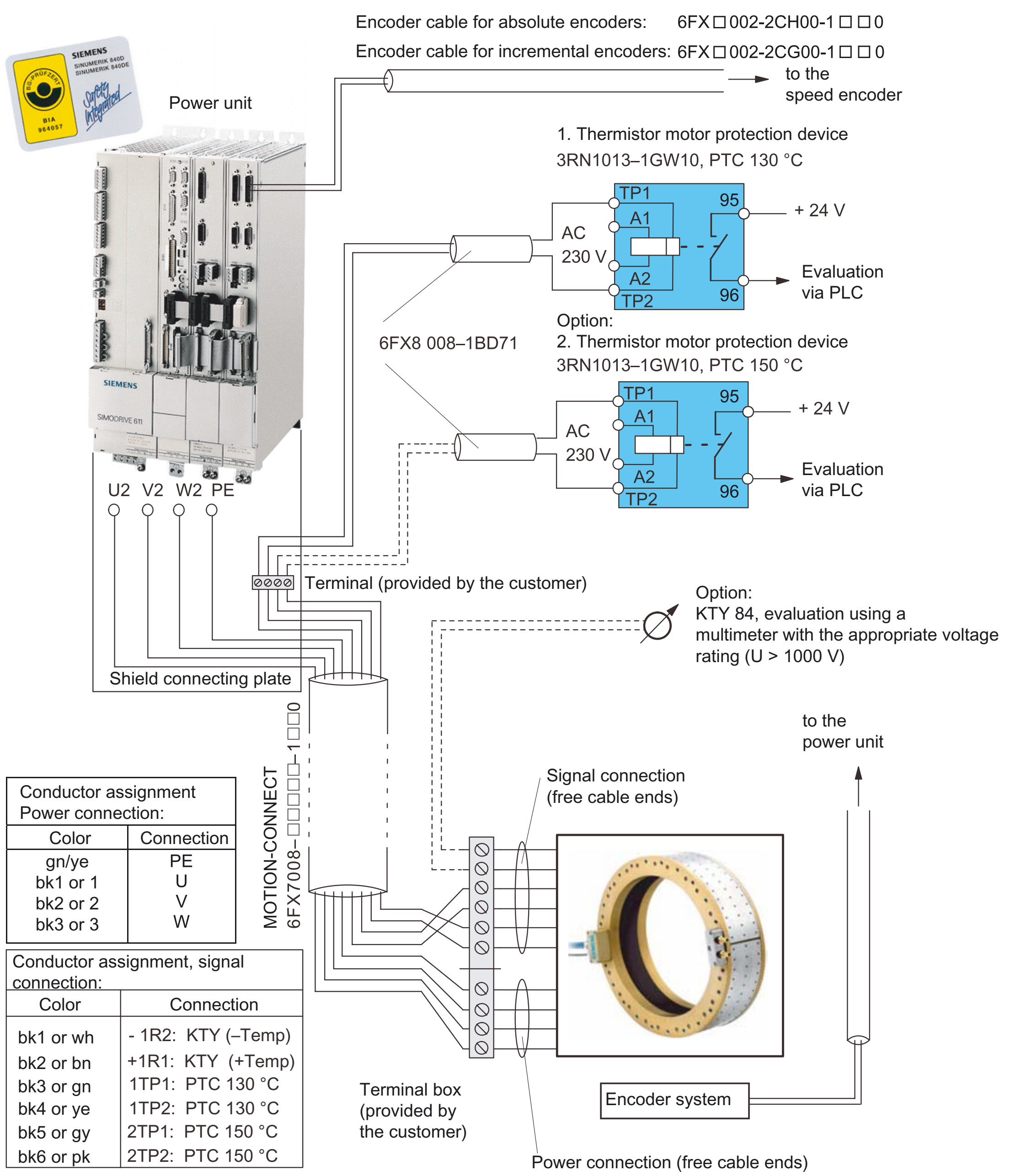
Note

You will find information on the SME9x in the Sensor Module External SME9x Manual.



Conductor assignment Power connection:	
Color	Connection
gn/ye	PE
bk1 or 1	U
bk2 or 2	V
bk3 or 3	W

Conductor assignment, signal connection:	
Color	Connection
bk1 or wh	- 1R2: KTY (–Temp)
bk2 or bn	+1R1: KTY (+Temp)
bk3 or gn	1TP1: PTC 130 °C
bk4 or ye	1TP2: PTC 130 °C
bk5 or gy	2TP1: PTC 150 °C
bk6 or pk	2TP2: PTC 150 °C

If only the PTC 130 °C is evaluated, then a maximum of 1 second after the shutdown signal, the stator must be in a no-current condition.

Figure 3-11: System integration with connection of the PTC sensors via the thermistor motor protection device

Accuracy

The accuracy of a direct drive with torque motor is defined by:

- the mechanical machine design
- the control system being used
- encoder resolution

Mechanical system

The machine accuracy of a drive system with torque motor that can be achieved is influenced by:

- mechanical stiffness of the system
- running smoothness – free of vibration

The running smoothness in the axial and radial directions depends on the bearing design and its precision. The specifications that must be fulfilled are achieved by using the appropriate axis design.

Control quality

The control quality of a direct drive with torque motor is defined by the following factors:

- stiffness of the drive system (dynamic quality of the housing and mechanical machine design, bearings, encoder mounting)
- the precision when mounting and adjusting the encoder system
- quantization of the angular signal and the velocity signal (the number of encoder pulses and their multiplication in the encoder evaluation of the drive converter per axis revolution) are decisive
- Sampling times of the current, speed and position controllers

3.4.2 Encoders

The encoder system has various functions:

- speed actual value encoder for the closed-loop speed control

- position encoder for the closed-loop position control
- rotor position encoder (commutation)

The encoder system is not included in the scope of supply. Unfortunately, it is not possible to list suitable encoders due to the wide range of different applications.

Motor encoder specifications

If automatic, motion-based or induction-based rotor position identification (SIMODRIVE 611 digital from software release 6.3 and SIMODRIVE 611 universal HR from software release 6.1) is excluded (refer to Chapter "Commissioning"), an absolute encoder with EnDat interface is required for operation.

Warning

When replacing an encoder it must be ensured that the commutation angle is correctly adjusted with respect to the motor voltage (EMF). Also refer to "General information about adjustment" on Page 62. Only appropriately trained personnel may carry-out this particular adjustment.

If the adjustment is not correct then this can result in uncontrolled axis motion.

- absolute angular encoders with EnDat (e.g. RCN 727, Heidenhain), incremental angular encoders ($1V_{pp}$) (e.g. RON 786, ERA 180, ERA 700, ERA 800, Heidenhain)

- minimum encoder pulse number, z_{min} = 2048
- maximum encoder pulse number, z_{max} = 65535

Recommended encoder pulse numbers for the following applications:

- rotary motion $z1 > 2p \cdot 85$

- positioning $z2 > 2 \cdot 360° / (i \cdot \Delta\varphi)$

The higher value from the calculation z1, z2 should always be used.

Explanations:

z1 = minimum encoder pulse number for adequate smooth running – free of vibration

z2 = minimum encoder pulse number for good positioning accuracy

p = number of pole pairs of the motor

i = pulse multiplication of the encoder evaluation (e.g. i = 2048 for SIMODRIVE 611 digital with Performance or High-Performance control modules)

$\Delta\varphi$ = specified positioning accuracy in [Degrees]

Calculation example

The following quantities are given:

2p = 44

i = 2048

$\Delta\varphi$ = $(0.1 \cdot 10^{-3})\,°$

If these quantities are used in the above specified formulas, then the following is obtained:

$z1 = 44 \cdot 85 = 3740$

$z2 = 2 \cdot 360° / (2048 \cdot (0.1 \cdot 10^{-3})\,°) = 3516$

Summary:

It is recommended that the encoder has a pulse number of between 3740 and 65535.

Note

Measuring systems from approx. 10 000 pulses per revolution are advisable in order to achieve a good closed-loop dynamic performance (high k_V factor), fast positioning without overshoot and for good smooth running operation.

Note

The permissible mechanical speed and the permissible limit frequency of the encoder and the control module should be carefully observed. The appropriate manufacturer's documentation must be carefully observed when engineering, mounting/installing and adjusting the encoder system!

Notice

We do not guarantee the characteristics and quality of third-party products. Please carefully observe the detailed text in the Foreword.

To protect against dirt, the area around the encoder in the mechanical axis assembly of the built-in torque motor must have degree of protection IP54 according to DIN VDE 0530 Part 5.

General information about adjustment

The adjustment can be made in two ways. In this case the motor must have a positive direction of rotation.

a) A zero crossover of the EMF V_{U-Y} (phase U with respect to the neutral point) with a positive gradient must coincide with the falling edge of the MSB (Most Significant Bit) of the "normalized electrical rotor position" within one revolution.

b) A zero crossover of the EMF V_{U-Y} (phase U with respect to the neutral point) with a positive gradient must coincide with the falling edge of the electrical rotor position.

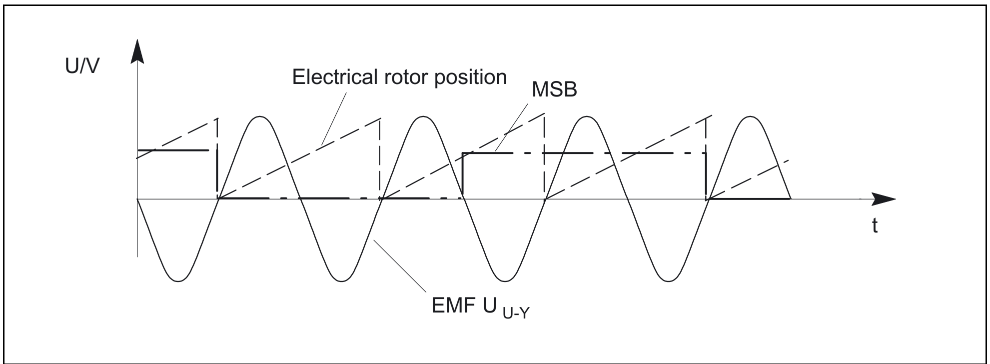


Figure 3-12: Signal sequence and assignment for a positive direction of rotation (clockwise direction rotation when viewing the drive end)

Also refer to the drive converter documentation.

3.4.3 Bearings

1FW6 torque motors are built-in motors for directly driven rotary or swivelling axes. When mounting and installing a complete drive unit, in addition to the angular encoder system, bearings are required between the stator and rotor.

Bearings are selected depending on the following factors:

- geometrical requirements (inner and outer diameter)
- speed
- load (absolute value, direction)
- stiffness (precision, pre-tensioning)

Warning

Bearing currents and static charging of the rotor:

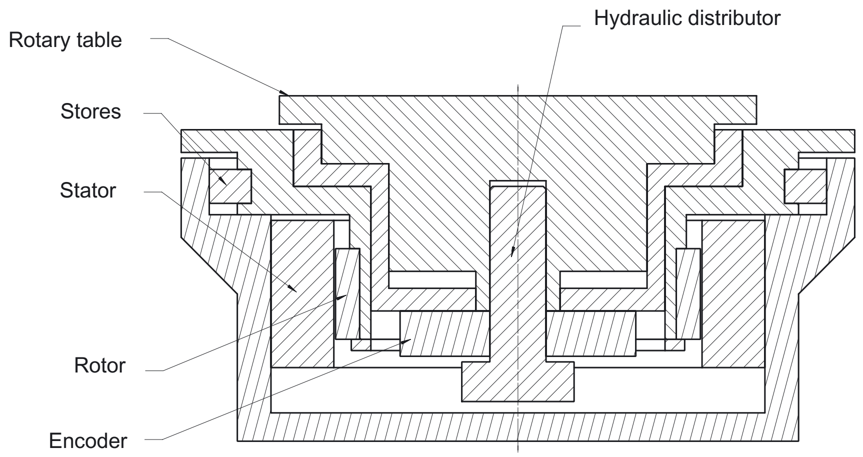
It is possible that the rotor is statically charged-up depending on the design and the arrangement of the bearings!

Counter-measures - e.g. bearings are mounted so that they are insulated or grounding measures are applied.

Note

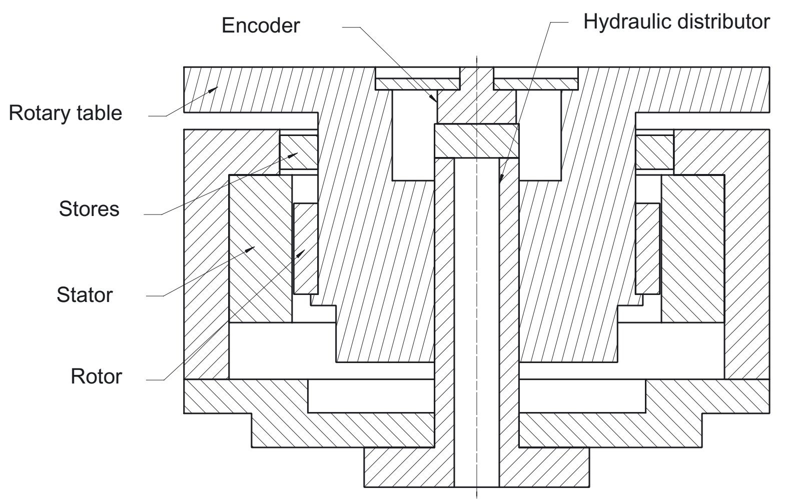
Radial forces act between the stator and rotor; these must be taken into account when selecting the bearings – also refer to Chapter "Motor installation".

Favorable encoder location



- Short distance between the motor and motor encoder
- Stiff motor encoder mounting
- No force between the motor and motor encoder

Unfavorable encoder location



- Large distance between the motor and motor encoder
- Low stiffness as a result of an excessively thin plate to mount the motor encoder
- Force between the motor and motor encoder

Figure 3-13: Installation - diagram (example)

Note

Other examples are provided in the Chapter "Motor installation and commissioning".

3.5 Interfaces

3.5.1 Electrical connection system

Power connection

The power connection is fed-out at the face side of the stator (NDE, refer to Figure 3-14 ff). It is a cable whose open cable ends must be connected in a terminal box provided by the machinery construction OEM. Sufficient installation space must be provided in the axis assembly.

Standard MOTION–CONNECT cables from the range of accessories for the SIMODRIVE 611 system can be used from this EMC-compliant terminal box (minimum degree of protection, IP54).

Information on the specifications of the motor feeder cables, refer to the end of this Chapter.

When required, the motors/stators can be ordered with connectors. Please contact your local Siemens office.

Note

The cable shields of the motor feeder cable and MOTION–CONNECT cable must be connected through the largest surface area at the terminal box using suitable cable glands.

Note

Under no circumstances may the connection block for the motor feeder cables (power and signal cables), provided at the motor be disassembled/removed. This will destroy the motor!

Temperature sensor connection

We recommend that the signal cable is connected to the SME9x using a connector; the output of the SME9x is connected at the drive converter. This means that the PTC temperature monitoring circuit and the temperature monitoring are directly implemented in the drive converter using KTY 84.
Also refer to Figure 3-10. Additional information, refer to the Chapter "Thermal motor protection".

Motor types that can be ordered

Table 3-5: Motor types that can be ordered

	Order No. [MLFB]	Cable outlet	Strain relief
Type A	1FW6090-0PA	Axial	Screw connection
	1FW6130-0PA	Axial	Screw connection
	1FW6160-0WA	Axial	Screw connection
	1FW6160-0VA	Radial	Screw connection
	1FW6190-0WA	Axial	Screw connection
	1FW6190-0VA	Radial	Screw connection
	1FW6230-0WA	Axial	Screw connection
	1FW6230-0VA	Radial	Screw connection
	1FW6290-0WA	Axial	Screw connection
	1FW6290-0VA	Radial	Screw connection
Type B CSA/UL certification	1FW6090-0PB	Axial	Sleeve
	1FW6090-0QB	Radial	Sleeve
	1FW6090-0NB	Tangential	Sleeve
	1FW6130-0PB	Axial	Sleeve
	1FW6130-0QB	Radial	Sleeve
	1FW6130-0NB	Tangential	Sleeve
	1FW6160-0WB	Axial	Sleeve
	1FW6160-0VB	Radial	Sleeve
	1FW6160-0TB	Tangential	Sleeve
	1FW6190-0WB	Axial	Sleeve
	1FW6190-0VB	Radial	Sleeve
	1FW6190-0TB	Tangential	Sleeve
	1FW6230-0WB	Axial	Sleeve
	1FW6230-0VB	Radial	Sleeve
	1FW6230-0TB	Tangential	Sleeve
	1FW6290-0WB	Axial	Sleeve
	1FW6290-0VB	Radial	Sleeve
	1FW6290-0TB	Tangential	Sleeve

Note

Motor type B is preferably used for new designs.

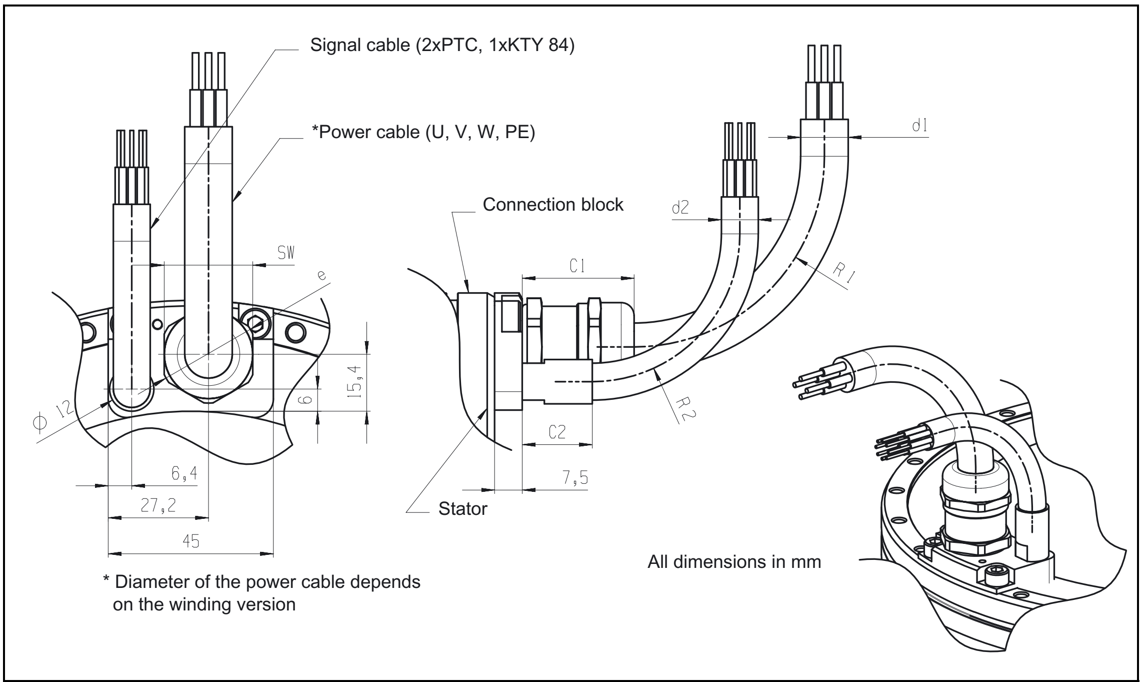


Figure 3-14: Axial electrical connection with gland for 1FW6090 (motor type A)

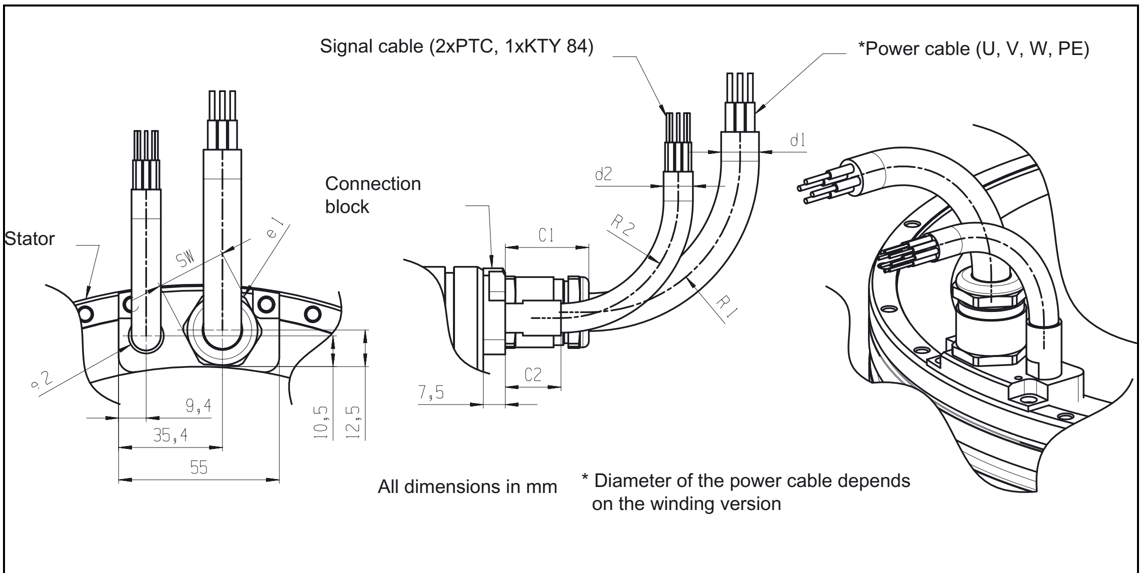


Figure 3-15: Axial electrical connection with gland for 1FW6130 (motor type A)

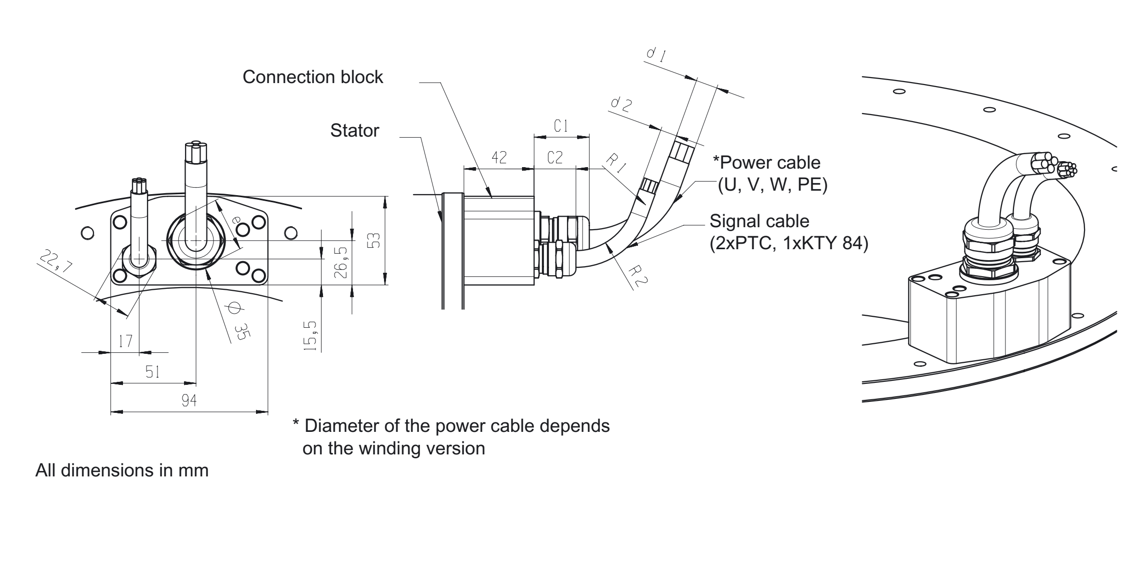


Figure 3-16: Axial electrical connection with gland for 1FW6160, 1FW6190 and 1FW6230 (motor type A)

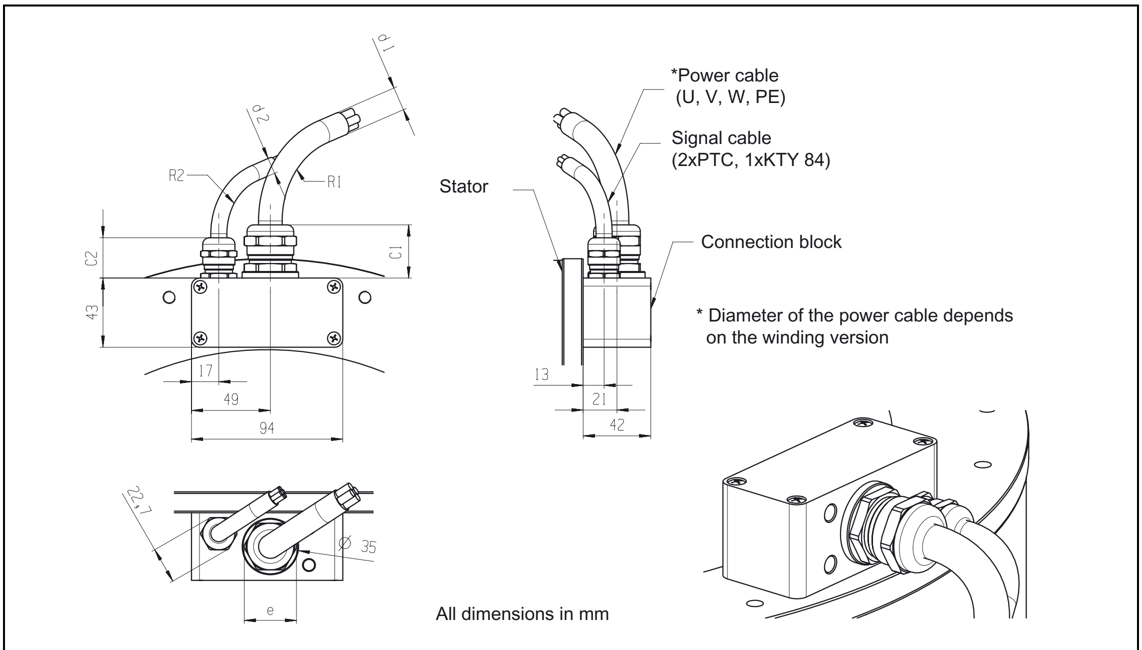


Figure 3-17: Radial electrical connection towards the outside with gland for 1FW6160, 1FW6190 and 1FW6230 up to 6 mm^2 conductor cross-section (motor type A)

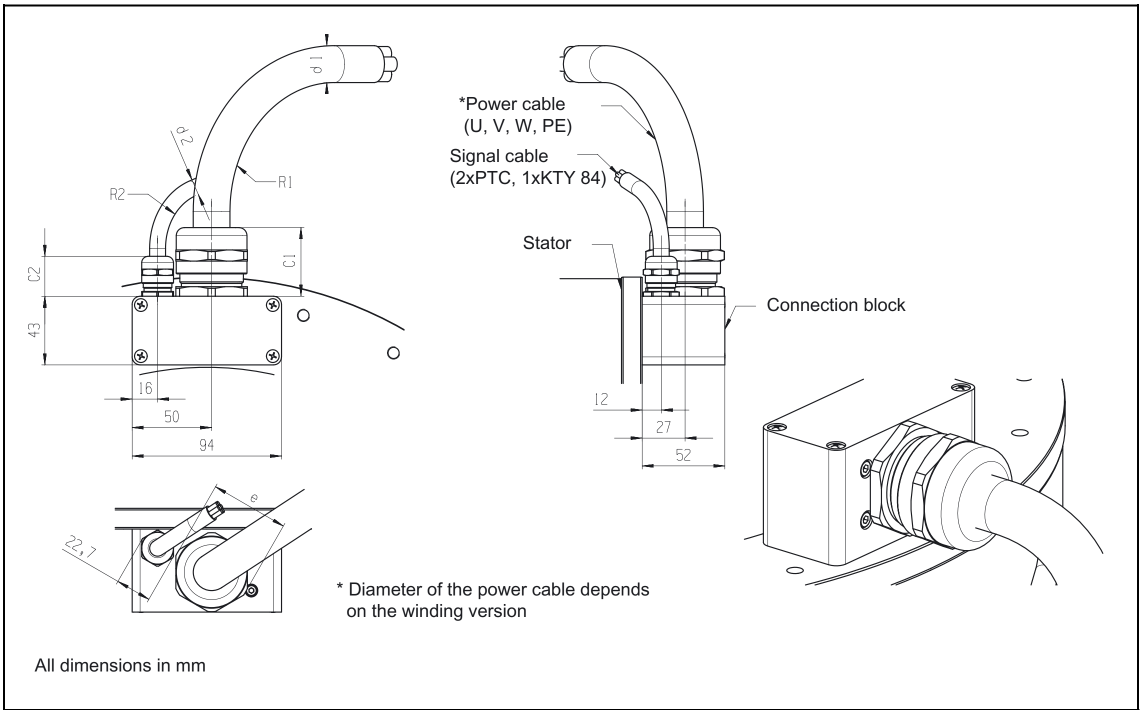


Figure 3-18: Radial electrical connection towards the outside with gland for 1FW6160, 1FW6190 and 1FW6230 from 10 mm^2 conductor cross-section (motor type A)

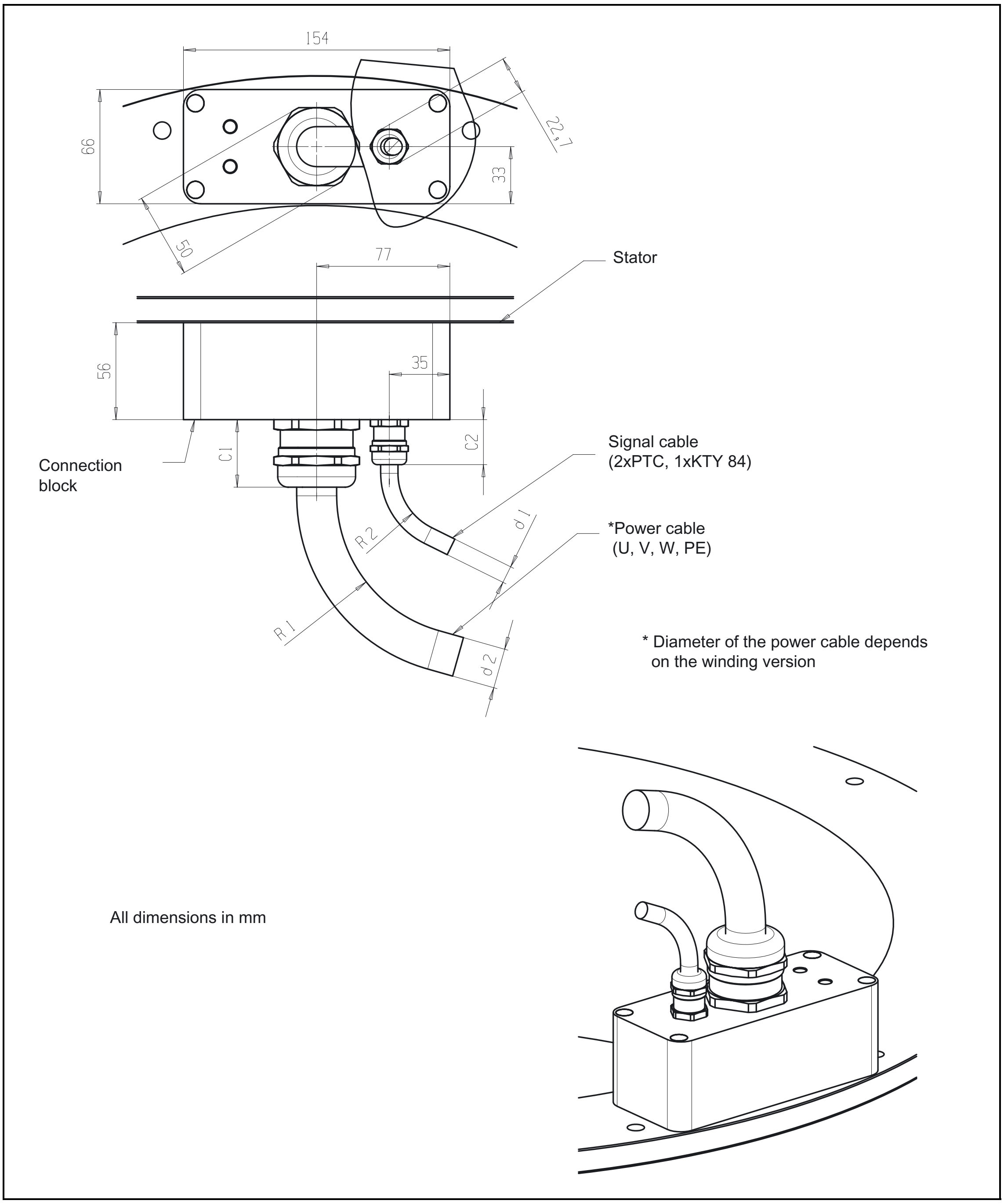


Figure 3-19: Axial electrical connection with gland for 1FW6290 (motor type A)

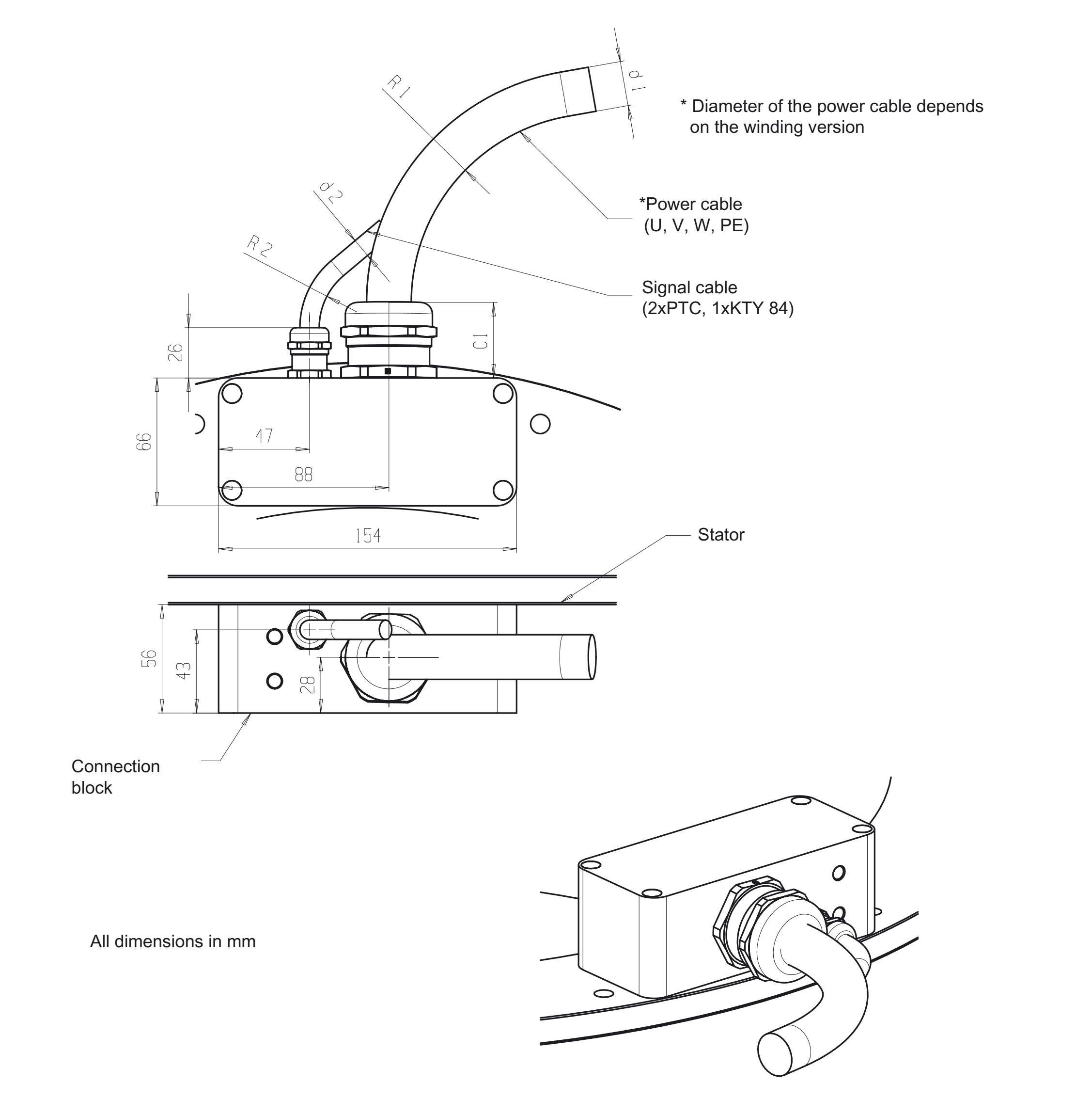


Figure 3-20: Radial electrical connection with gland for 1FW6290 (motor type A)

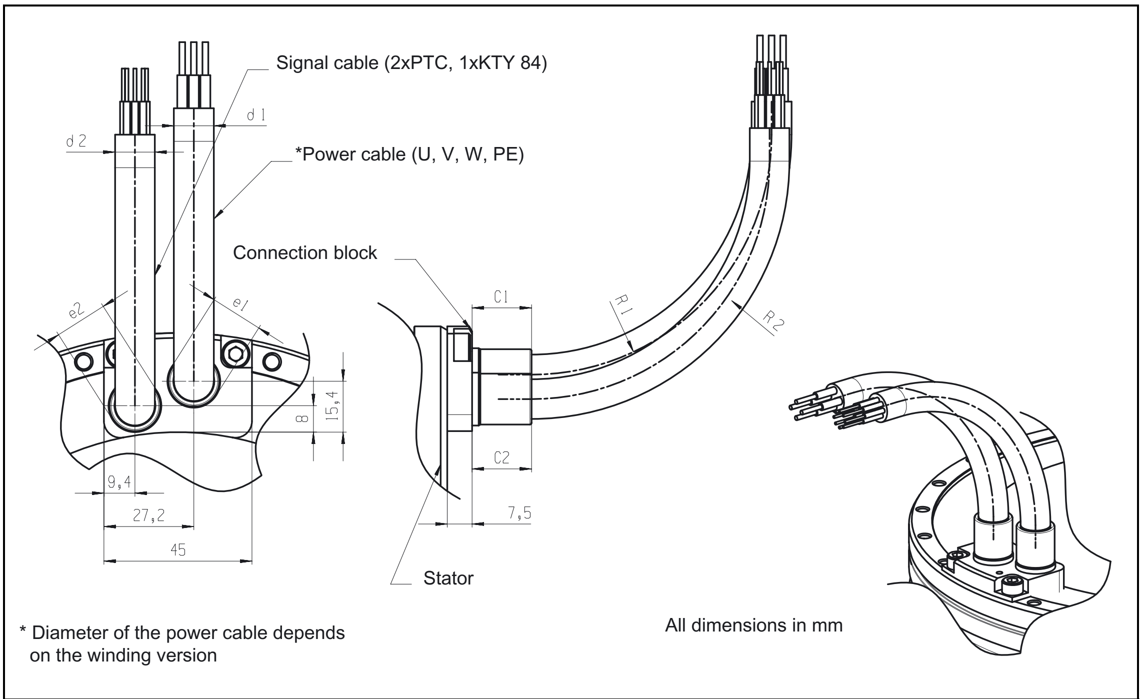


Figure 3-21: Axial electrical connection with sleeve for 1FW6090 (motor type B)

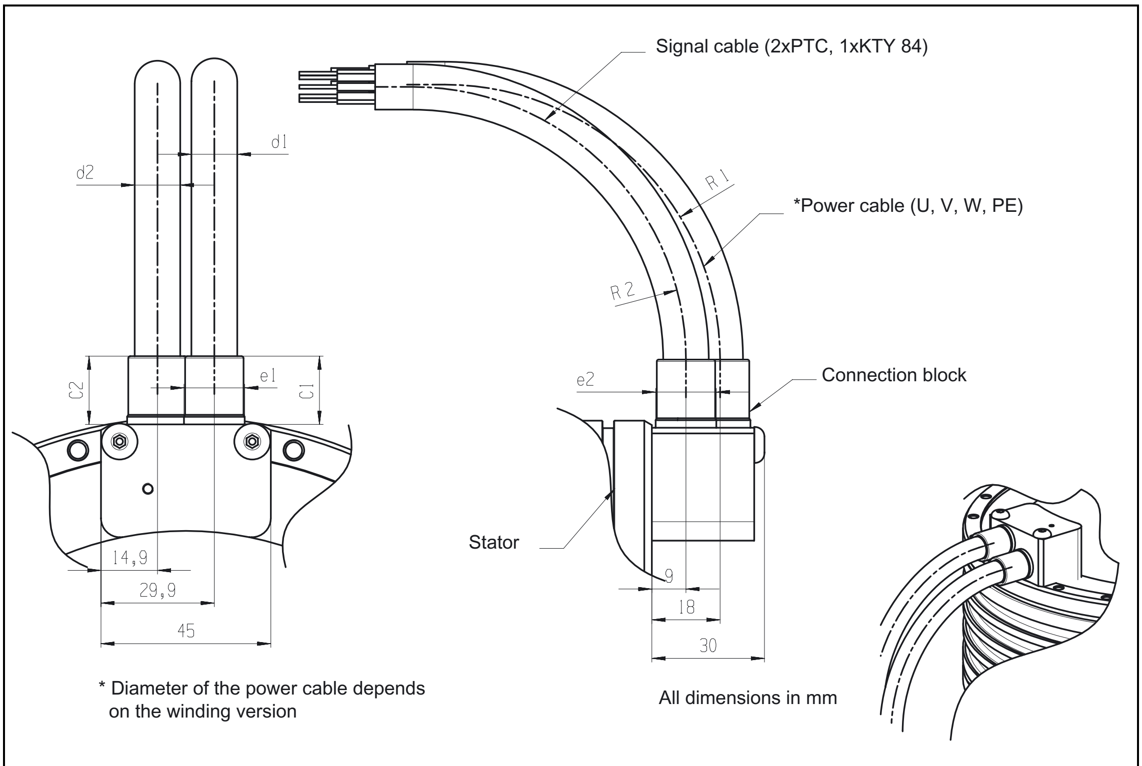


Figure 3-22: Radial electrical connection with sleeve for 1FW6090 (motor type B)

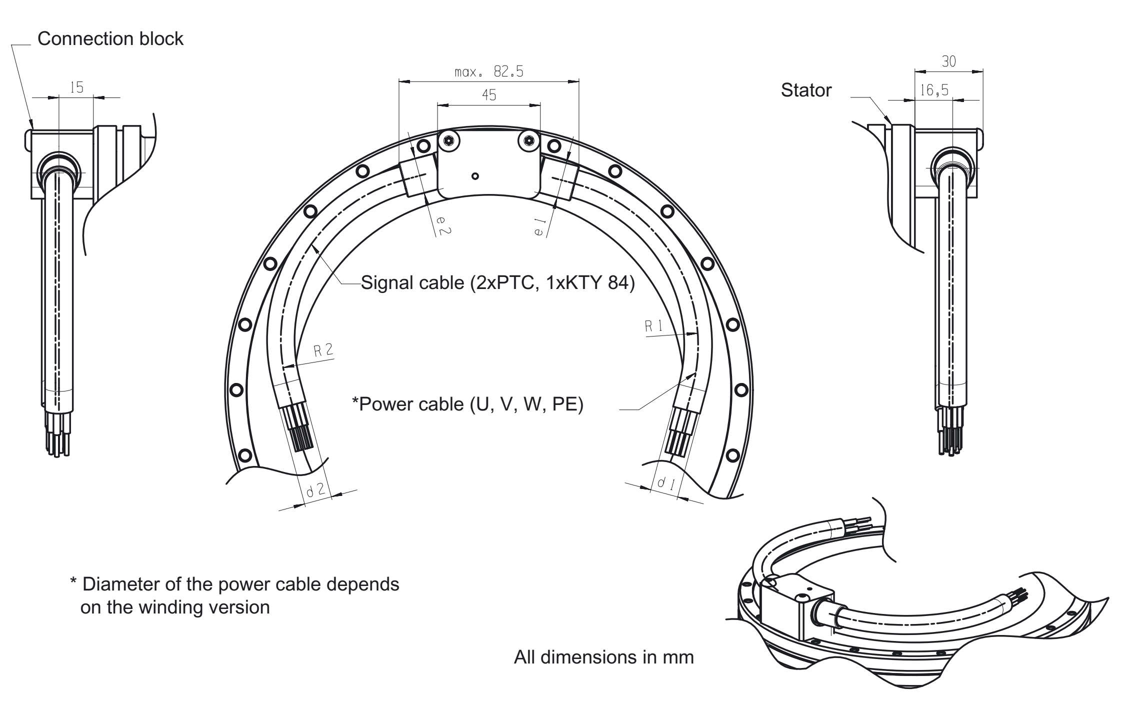


Bild 3-23: Tangential electrical connection with sleeve for 1FW6090 (motor type B)

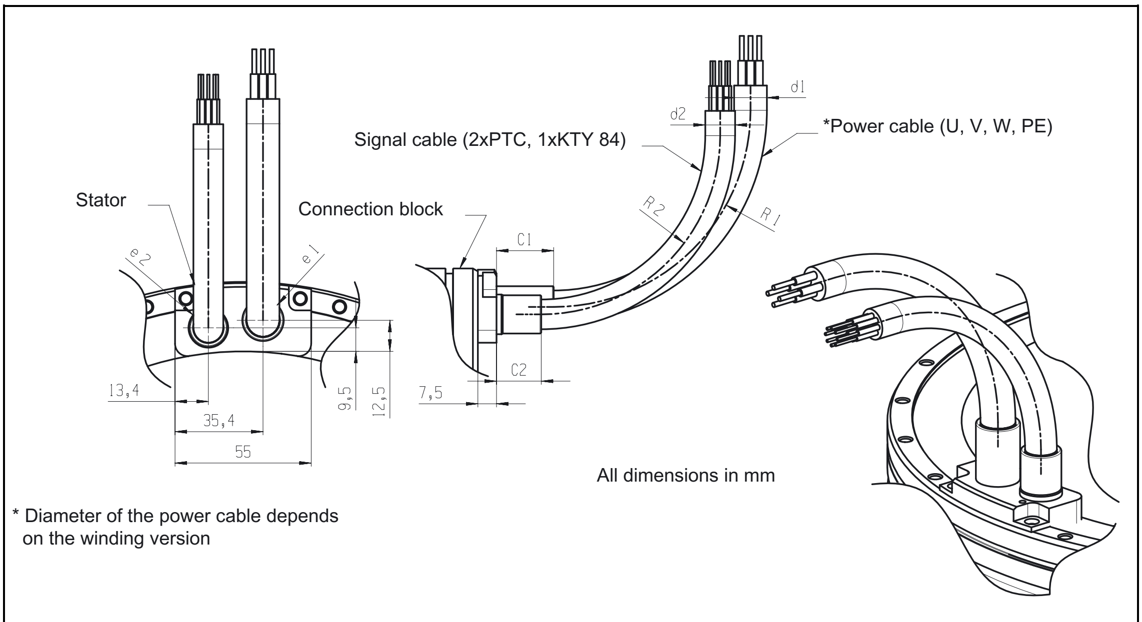


Figure 3-24: Axial electrical connection with sleeve for 1FW6130 (motor type B)

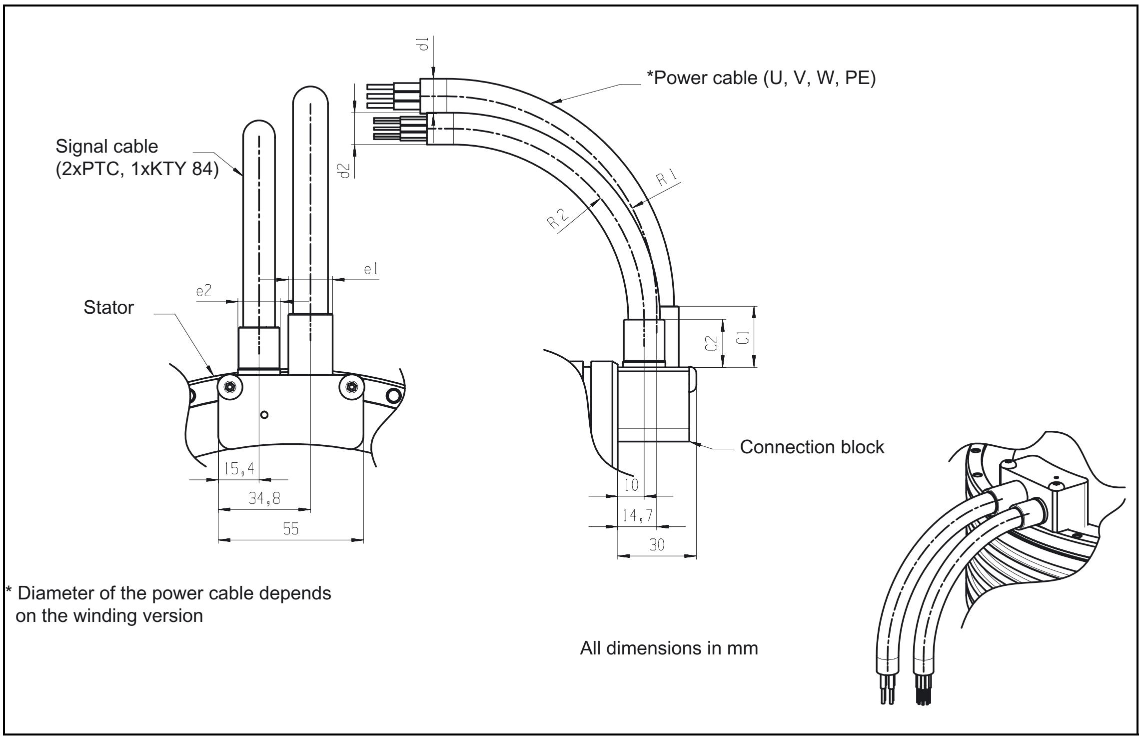


Figure 3-25: Radial electrical connection with sleeve for 1FW6130 (motor type B)

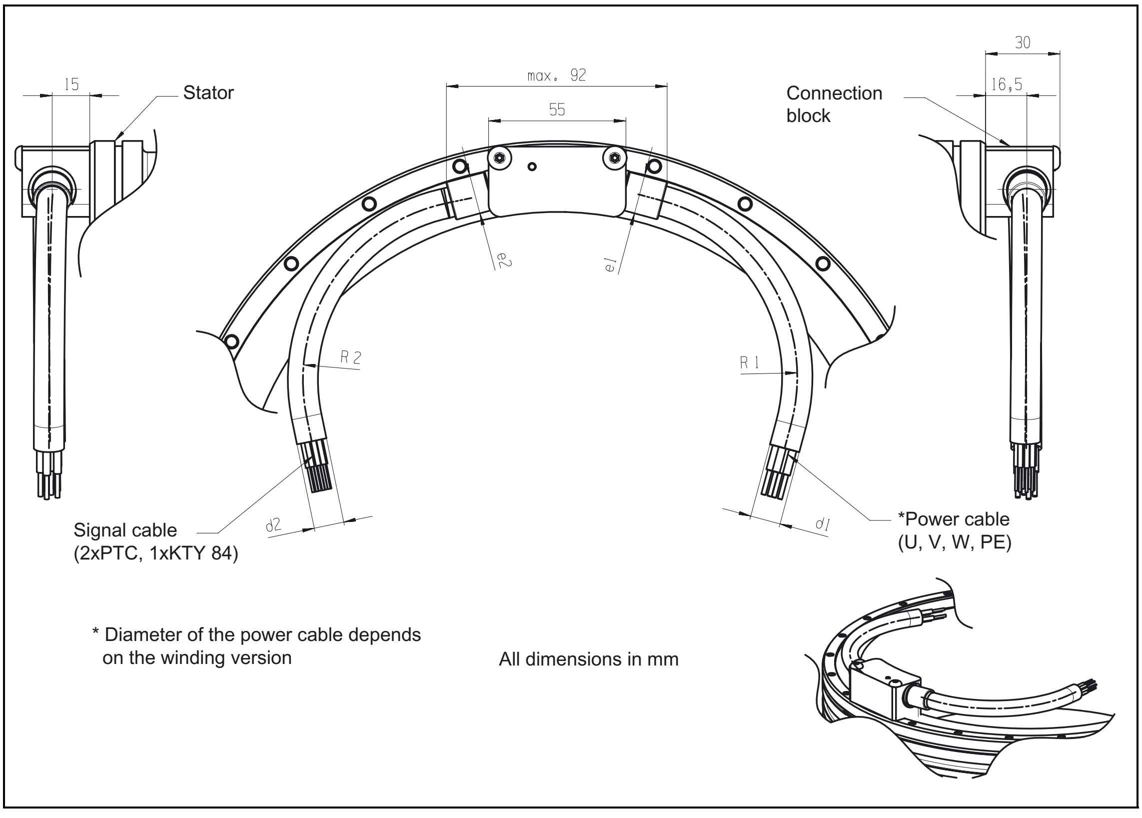


Figure 3-26: Tangential electrical connection with sleeve for 1FW6130 (motor type B)

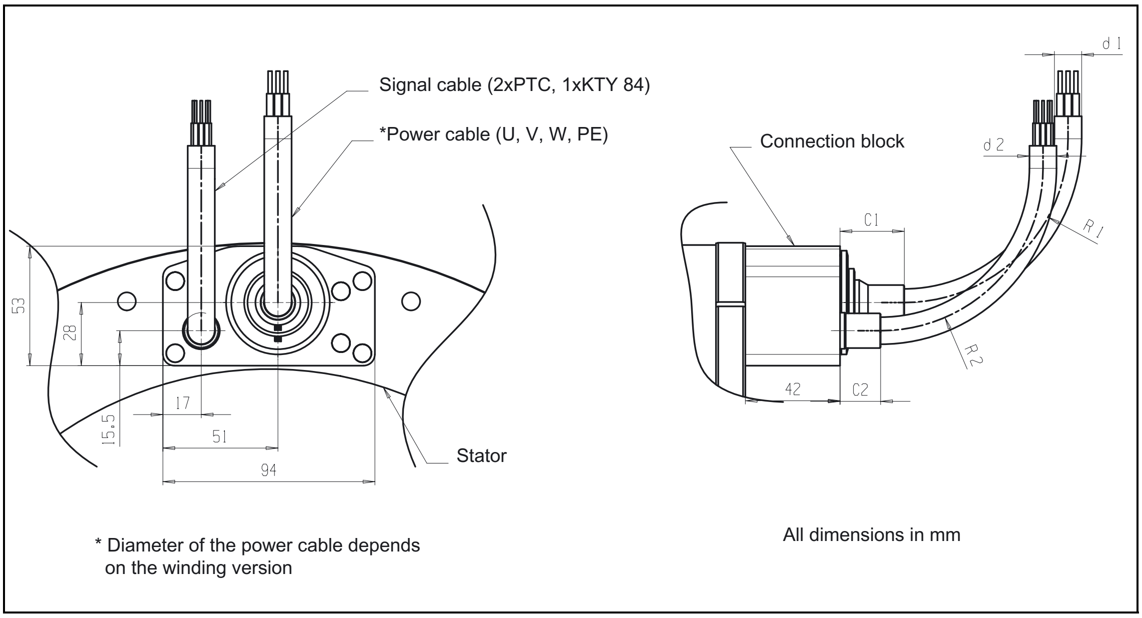


Figure 3-27: Axial electrical connection with sleeve for 1FW6160, 1FW6190 and 1FW6230 (motor type B)

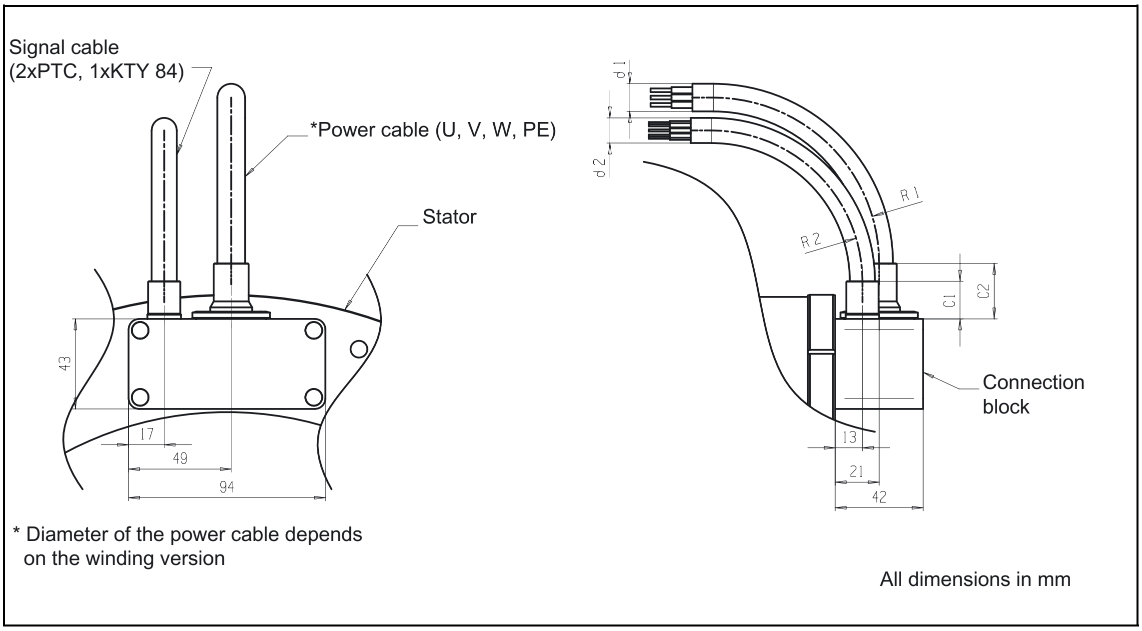


Figure 3-28: Radial electrical connection with sleeve for 1FW6160, 1FW6190 and 1FW6230 up to 6 mm^2 conductor cross-section (motor type B)

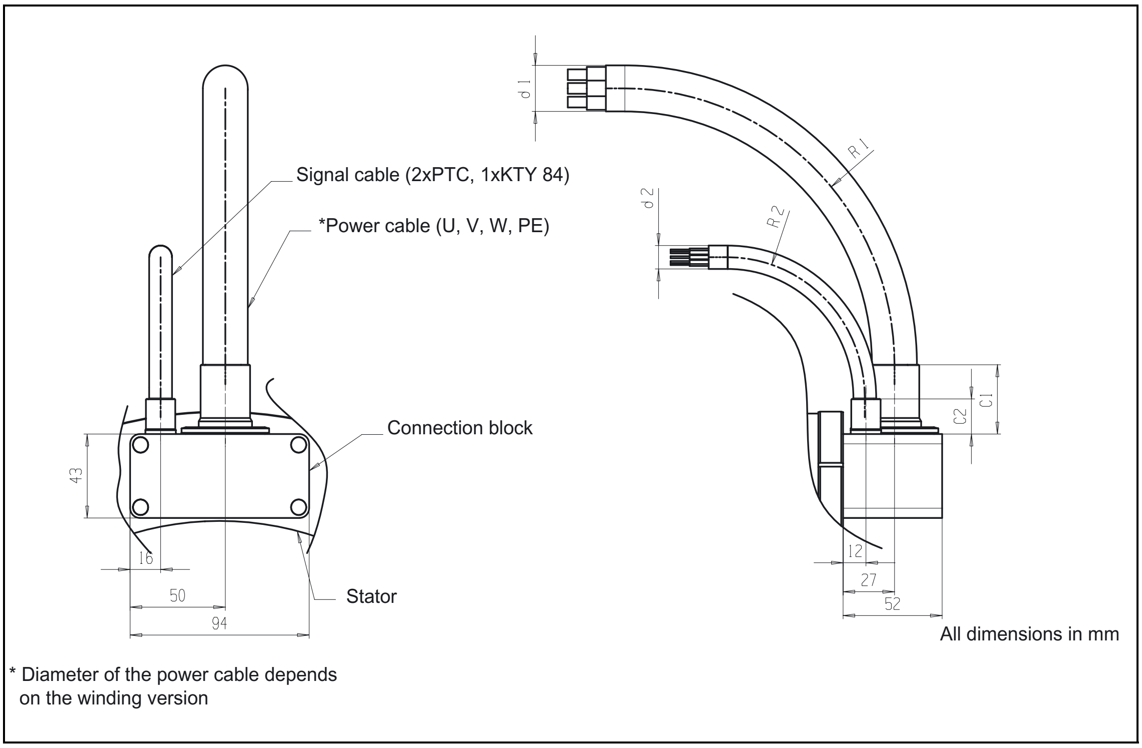


Figure 3-29: Radial electrical connection with sleeve for 1FW6160, 1FW6190 and 1FW6230 from 10 mm^2 conductor cross-section (motor type B)

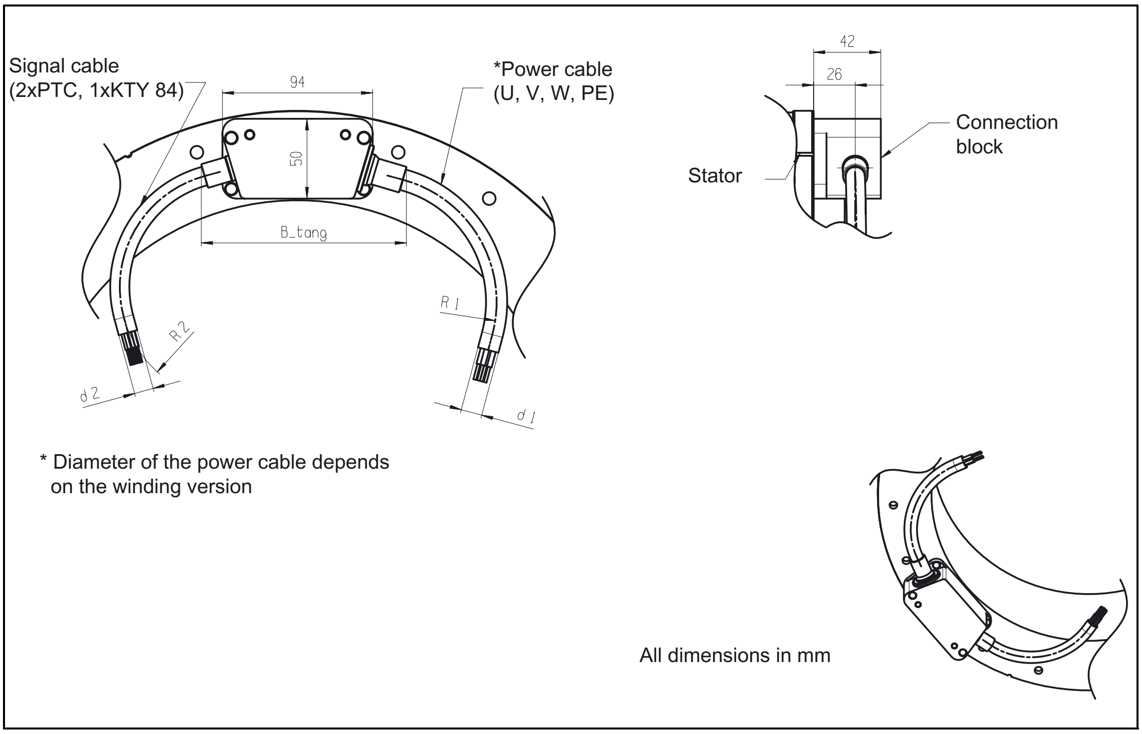


Figure 3-30: Tangential electrical connection with sleeve for 1FW6160, 1FW6190 and 1FW6230 (motor type B)

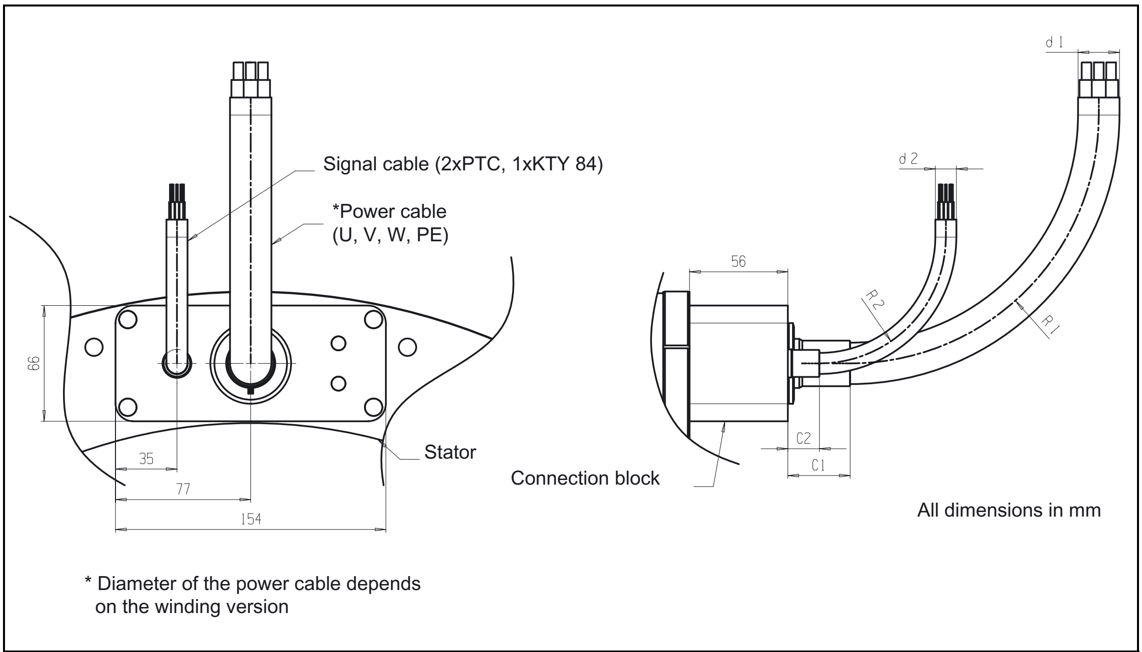


Figure 3-31: Axial electrical connection with sleeve for 1FW6290 (motor type B)

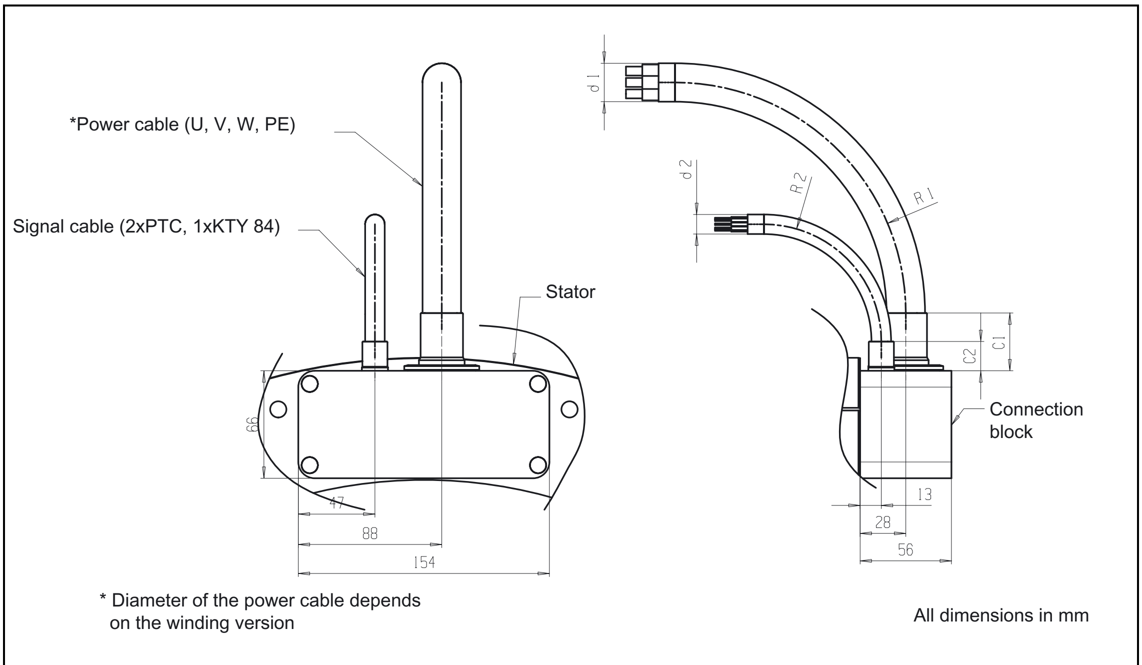


Figure 3-32: Radial electrical connection with sleeve for 1FW6290 (motor type B)

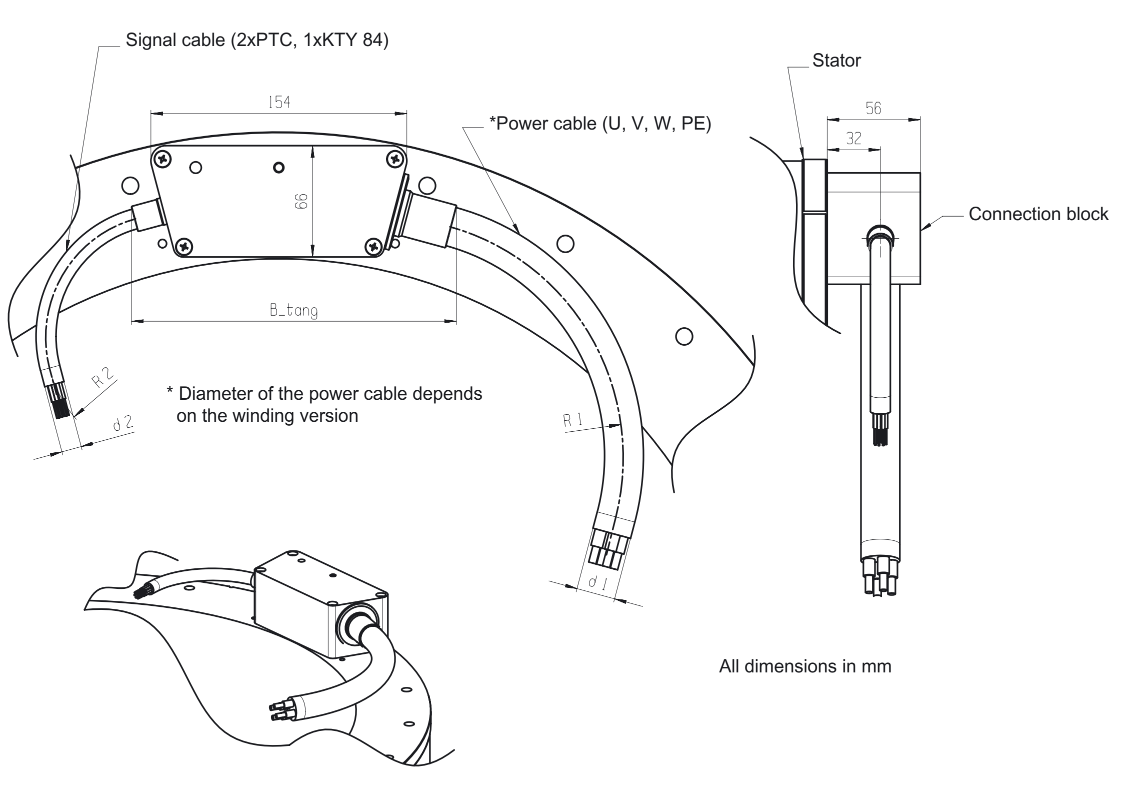


Figure 3-33: Tangential electrical connection with sleeve for 1FW6290 (motor type B)

Motor feeder cables

Built-in torque motors are supplied with one 2 m power cable and one 2 m signal cable with free cable ends.

The length of the power and signal cables from the motor to the drive converter must not exceed 50m.

Notice

The motor feeder cables permanently connected to the motor are not designed for high rates of acceleration and when damaged, cannot be replaced. In order to avoid wear, the motor cables should not be routed using a power (drag) chain.

System integration, refer to Figure 3-10 ff; data on the motor feeder cables, refer to the diagrams on the electrical connections, following tables and Catalog NC 60.

Specification of motor feeder cables for type A motors:

Specifications of the motor power cable:

- Outer sheath: TPE according to UL 20334, oil resistant, temperature range –20°C up to +120°C
- Conductor insulation: TPE according to UL1698; 0.6/1 KV

Specification of the motor signal cable:

- Outer sheath: TPE according to UL 20334, oil resistant, temperature range –20 °C up to +120°C
- Conductor insulation: TPE according to UL1790; 0.3/0.5 KV

Specification of motor feeder cables for type B motors:

The built-in torque motors are supplied with MOTION-CONNECT cables as listed in Catalog NC 60 - the technical data is specified there:

Power cable: MOTION-CONNECT 800, type 6FX8

Signal cable: MOTION-CONNECT 700, type 6FX7

Table 3-6: Data of the motor feeder cable (motor type A)

Motor type	Power cable at the stator					Signal cable at the stator			
	Diameter	4 x power conductors	Bending radius, min.	Height of the gland	Gland width	Diameter	6 x control conductors	Bending radius, min.	Height of the gland
	d1		R1	C1	e	d2		R2	C2
	mm	mm^2	mm	mm	mm	mm	mm^2	mm	mm
1FW6090-xxA05-0Fxx	11.3	1.5	45	29	26.4	10	0.5	40	19
1FW6090-xxA05-0Kxx	11.3	1.5	45	29	26.4	10	0.5	40	19
1FW6090-xxA07-0Kxx	11.3	1.5	45	29	26.4	10	0.5	40	19
1FW6090-xxA07-1Jxx	12.9	2.5	52	29	26.4	10	0.5	40	19
1FW6090-xxA10-0Kxx	11.3	1.5	45	29	26.4	10	0.5	40	19
1FW6090-xxA10-1Jxx	12.9	2.5	52	29	26.4	10	0.5	40	19
1FW6090-xxA15-1Jxx	12.9	2.5	52	29	26.4	10	0.5	40	19
1FW6090-xxA15-2Jxx	14.7	4	59	28.5	26.7	10	0.5	40	19
1FW6130-xxA05-0Kxx	11.3	1.5	45	29	26.4	10	0.5	40	19
1FW6130-xxA05-1Jxx	12.9	2.5	52	29	26.4	10	0.5	40	19
1FW6130-xxA07-0Kxx	11.3	1.5	45	29	26.4	10	0.5	40	19
1FW6130-xxA07-1Jxx	12.9	2.5	52	29	26.4	10	0.5	40	19
1FW6130-xxA10-1Jxx	12.9	2.5	52	29	26.4	10	0.5	40	19
1FW6130-xxA10-2Jxx	14.7	4	59	28.5	26.7	10	0.5	40	19
1FW6130-xxA15-1Jxx	12.9	2.5	52	29	26.4	10	0.5	40	19
1FW6130-xxA15-2Jxx	14.7	4	59	28.5	26.7	10	0.5	40	19
1FW6160-xxA05-1Jxx	12.9	2.5	52	34	32.5	10	0.5	40	26
1FW6160-xxA05-2Jxx	14.7	4	59	34	32.5	10	0.5	40	26
1FW6160-xxA07-1Jxx	12.9	2.5	52	34	32.5	10	0.5	40	26
1FW6160-xxA07-2Jxx	14.7	4	59	34	32.5	10	0.5	40	26
1FW6160-xxA10-1Jxx	12.9	2.5	52	34	32.5	10	0.5	40	26
1FW6160-xxA10-2Jxx	14.7	4	59	34	32.5	10	0.5	40	26
1FW6160-xxA15-2Jxx	14.7	4	59	34	32.5	10	0.5	40	26
1FW6160-xxA15-5Gxx	27.1	16	108	39	51.2	10	0.5	40	26
1FW6190-xxA05-1Jxx	12.9	2.5	52	34	32.5	10	0.5	40	26
1FW6190-xxA05-2Jxx	14.7	4	59	34	32.5	10	0.5	40	26
1FW6190-xxA07-1Jxx	12.9	2.5	52	34	32.5	10	0.5	40	26
1FW6190-xxA07-2Jxx	14.7	4	59	34	32.5	10	0.5	40	26
1FW6190-xxA10-1Jxx	12.9	2.5	52	34	32.5	10	0.5	40	26
1FW6190-xxA10-2Jxx	14.7	4	59	34	32.5	10	0.5	40	26
1FW6190-xxA15-2Jxx	14.7	4	59	34	32.5	10	0.5	40	26
1FW6190-xxA15-5Gxx	27.1	16	108	39	51.2	10	0.5	40	26

Motor type	Power cable at the stator					Signal cable at the stator			
	Diameter	4 x power conductors	Bending radius, min.	Height of the gland	Gland width	Diameter	6 x control conductors	Bending radius, min.	Height of the gland
	d1		R1	C1	e	d2		R2	C2
	mm	mm^2	mm	mm	mm	mm	mm^2	mm	mm
1FW6230-xxA05-1Jxx	12.9	2.5	52	34	32.5	10	0.5	40	26
1FW6230-xxA05-2Jxx	14.7	4	59	34	32.5	10	0.5	40	26
1FW6230-xxA07-1Jxx	12.9	2.5	52	34	32.5	10	0.5	40	26
1FW6230-xxA07-2Jxx	14.7	4	59	34	32.5	10	0.5	40	26
1FW6230-xxA10-2Jxx	14.7	4	59	34	32.5	10	0.5	40	26
1FW6230-xxA10-5Gxx	27.1	16	108	39	51.2	10	0.5	40	26
1FW6230-xxA15-4Cxx	15.6	6	75	40	40.5	10	0.5	40	26
1FW6230-xxA15-5Gxx	27.1	16	108	39	51.2	10	0.5	40	26
1FW6290-xxA15-7Axx	27.1	16	108	39	51.2	10	0.5	40	26

Table 3-7: Data of motor feeder cables (motor type B)

Motor type	Power cable at the stator				Signal cable at the stator			
	Diameter	4 x power conductors	Bending radius, min.	Height of the sleeve	Diameter	6 x control conductors + 1 x PE	Bending radius, min.	Height of the sleeve
	d1		R1	C1	d2		R2	C2
	mm	mm^2	mm	mm	mm	mm^2	mm	mm
1FW6090-xxB05-0Fxx	12.1	2.5	73	18	12	6 x 0.5 + 1 x 1.0	48	18
1FW6090-xxB05-0Kxx	12.1	2.5	73	18	12	6 x 0.5 + 1 x 1.0	48	18
1FW6090-xxB07-0Kxx	12.1	2.5	73	18	12	6 x 0.5 + 1 x 1.0	48	18
1FW6090-xxB07-1Jxx	12.1	2.5	73	18	12	6 x 0.5 + 1 x 1.0	48	18
1FW6090-xxB10-0Kxx	12.1	2.5	73	18	12	6 x 0.5 + 1 x 1.0	48	18
1FW6090-xxB10-1Jxx	12.1	2.5	73	18	12	6 x 0.5 + 1 x 1.0	48	18
1FW6090-xxB15-1Jxx	12.1	2.5	73	18	12	6 x 0.5 + 1 x 1.0	48	18
1FW6090-xxB15-2Jxx	13.2	4.0	79	23	12	6 x 0.5 + 1 x 1.0	48	18
1FW6130-xxB05-0Kxx	12.1	2.5	73	18	12	6 x 0.5 + 1 x 1.0	48	18
1FW6130-xxB05-1Jxx	12.1	2.5	73	18	12	6 x 0.5 + 1 x 1.0	48	18
1FW6130-xxB07-0Kxx	12.1	2.5	73	18	12	6 x 0.5 + 1 x 1.0	48	18
1FW6130-xxB07-1Jxx	12.1	2.5	73	18	12	6 x 0.5 + 1 x 1.0	48	18
1FW6130-xxB10-1Jxx	12.1	2.5	73	18	12	6 x 0.5 + 1 x 1.0	48	18
1FW6130-xxB10-2Jxx	13.2	4.0	79	23	12	6 x 0.5 + 1 x 1.0	48	18
1FW6130-xxB15-1Jxx	12.1	2.5	73	18	12	6 x 0.5 + 1 x 1.0	48	18
1FW6130-xxB15-2Jxx	13.2	4.0	79	23	12	6 x 0.5 + 1 x 1.0	48	18
1FW6160-xxB05-1Jxx	12.1	2.5	73	28.5	12	6 x 0.5 + 1 x 1.0	48	18
1FW6160-xxB05-2Jxx	13.2	4.0	79	29.5	12	6 x 0.5 + 1 x 1.0	48	18
1FW6160-xxB07-1Jxx	12.1	2.5	73	28.5	12	6 x 0.5 + 1 x 1.0	48	18
1FW6160-xxB07-2Jxx	13.2	4.0	79	29.5	12	6 x 0.5 + 1 x 1.0	48	18
1FW6160-xxB10-1Jxx	12.1	2.5	73	28.5	12	6 x 0.5 + 1 x 1.0	48	18
1FW6160-xxB10-2Jxx	13.2	4.0	79	29.5	12	6 x 0.5 + 1 x 1.0	48	18
1FW6160-xxB15-2Jxx	13.2	4.0	79	29.5	12	6 x 0.5 + 1 x 1.0	48	18
1FW6160-xxB15-5Gxx	23.6	16.0	142	35.5	12	6 x 0.5 + 1 x 1.0	48	18
1FW6190-xxB05-1Jxx	12.1	2.5	73	28.5	12	6 x 0.5 + 1 x 1.0	48	18
1FW6190-xxB05-2Jxx	13.2	4.0	79	29.5	12	6 x 0.5 + 1 x 1.0	48	18
1FW6190-xxB07-1Jxx	12.1	2.5	73	28.5	12	6 x 0.5 + 1 x 1.0	48	18

Motor type	Power cable at the stator				Signal cable at the stator			
	Diameter	4 x power conductors	Bending radius, min.	Height of the sleeve	Diameter	6 x control conductors + 1 x PE	Bending radius, min.	Height of the sleeve
	d1		R1	C1	d2		R2	C2
	mm	mm^2	mm	mm	mm	mm^2	mm	mm
1FW6190-xxB07-2Jxx	13.2	4.0	79	29.5	12	6 x 0.5 + 1 x 1.0	48	18
1FW6190-xxB10-1Jxx	12.1	2.5	73	28.5	12	6 x 0.5 + 1 x 1.0	48	18
1FW6190-xxB10-2Jxx	13.2	4.0	79	29.5	12	6 x 0.5 + 1 x 1.0	48	18
1FW6190-xxB15-2Jxx	13.2	4.0	79	29.5	12	6 x 0.5 + 1 x 1.0	48	18
1FW6190-xxB15-5Gxx	23.6	16.0	142	35.5	12	6 x 0.5 + 1 x 1.0	48	18
1FW6230-xxB05-1Jxx	12.1	2.5	73	28.5	12	6 x 0.5 + 1 x 1.0	48	18
1FW6230-xxB05-2Jxx	13.2	4.0	79	29.5	12	6 x 0.5 + 1 x 1.0	48	18
1FW6230-xxB07-1Jxx	12.1	2.5	73	28.5	12	6 x 0.5 + 1 x 1.0	48	18
1FW6230-xxB07-2Jxx	13.2	4.0	79	29.5	12	6 x 0.5 + 1 x 1.0	48	18
1FW6230-xxB10-2Jxx	13.2	4.0	79	29.5	12	6 x 0.5 + 1 x 1.0	48	18
1FW6230-xxB10-5Gxx	23.6	16.0	142	35.5	12	6 x 0.5 + 1 x 1.0	48	18
1FW6230-xxB15-4Cxx	16.0	6.0	96	31.5	12	6 x 0.5 + 1 x 1.0	48	18
1FW6230-xxB15-5Gxx	23.6	16.0	142	35.5	12	6 x 0.5 + 1 x 1.0	48	18
1FW6290-xxB15-7Axx	23.6	16.0	142	35.5	12	6 x 0.5 + 1 x 1.0	48	18

Note

For MOTION-CONNECT cables from the terminal box on the customer's side for power and signal connections, refer to Catalog NC 60.

3.5.2 Cooler connection system

Cooler connection system for motors with cooling jacket

For motors with jacket cooling, the cooling system is connected-up at the mechanical assembly. The cooling water pipe cross-sections depend on the cross-sections of the cooling grooves in the jacket. The grooves of the cooling jacket are sealed by the housing on the customer's side and the O-rings.

For built-in torque motors with cooling jacket, the cooling medium intake and outlet are realized through two holes in the axis assembly that the user must provide (refer to Figure 3-34).

In order to achieve optimum, uniform cooling over all of the cooling grooves, the intake for the cooling medium must be offset by an angle of 90° with respect to the cable outlet position for the electrical infeed. If another position is selected for the cooling medium intake and outlet, the cooling medium will be unevenly distributed in the cooling grooves. The most unfavorable position for the intake and outlet of the cooling medium is an angle of 90° in the counter-clockwise direction: In this case, cooling medium doesn't even flow through the first cooling groove.

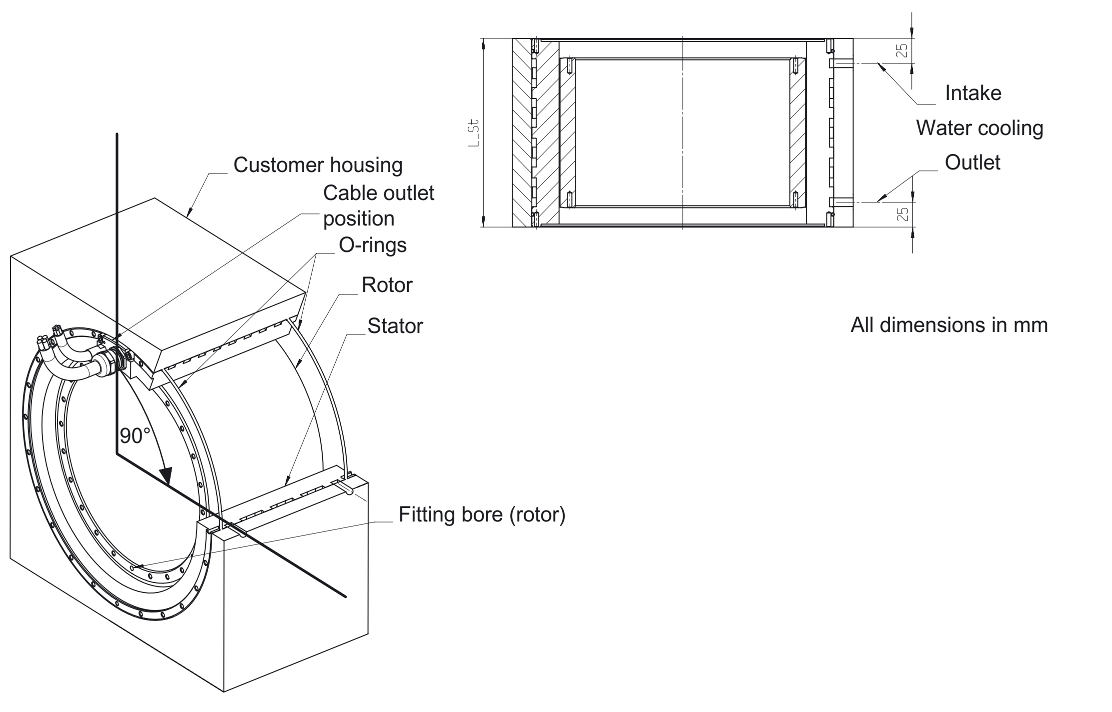


Figure 3-34: Cooler connection for 1FW6090 and 1FW6130 (example)

Cooler connection for motors with integrated cooling

For built-in torque motors with integrated cooling, no provisions have to be made at the machine assembly to connect the cooling. The connection for the precision and main coolers can be realized directly through the appropriate fittings (1/8" pipe thread, DIN 2999); whereby each cooling circuit can be separately connected.

Note

If the coolers are connected in series, the cooling medium must first flow through the precision cooler and then through the main cooler.

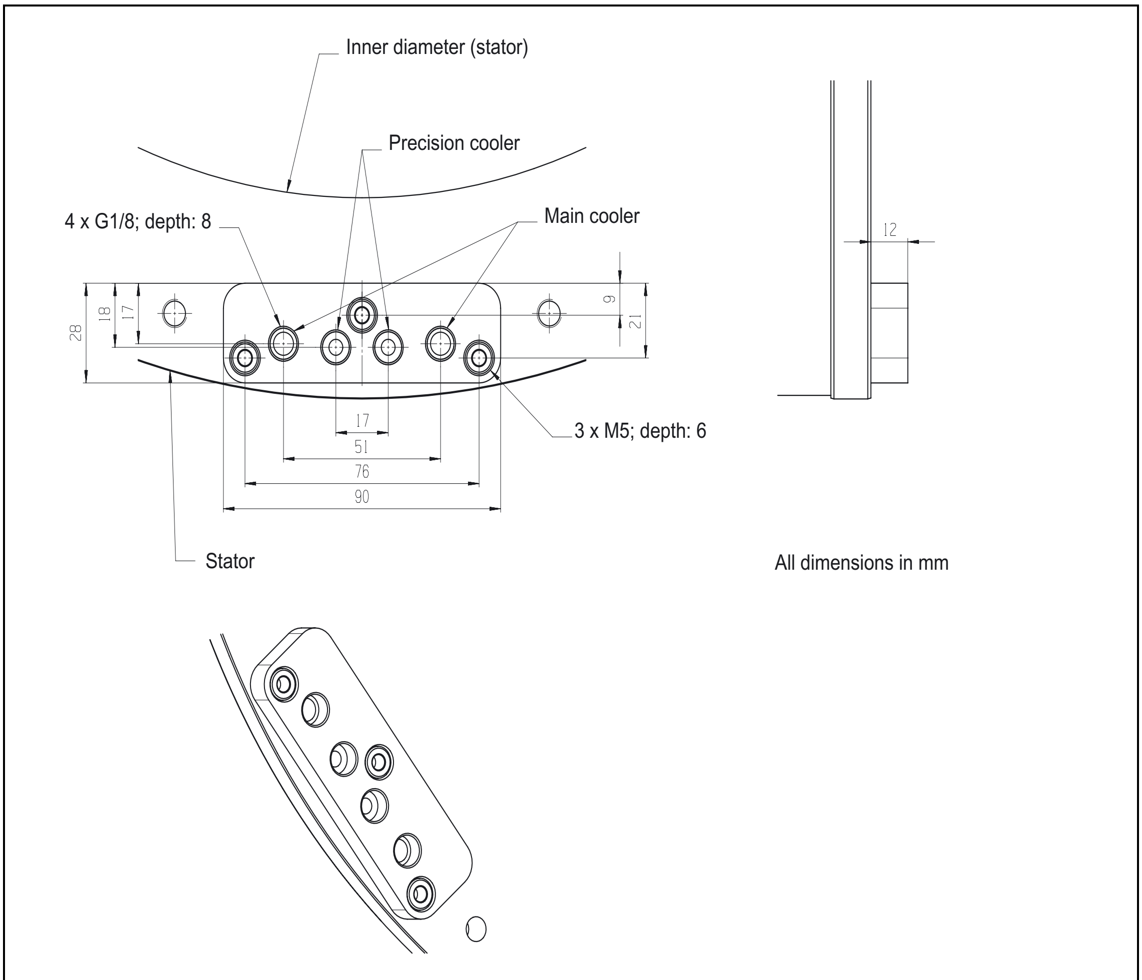


Figure 3-35: Cooling connection plate for 1FW6160, 1FW6190 and 1FW6230

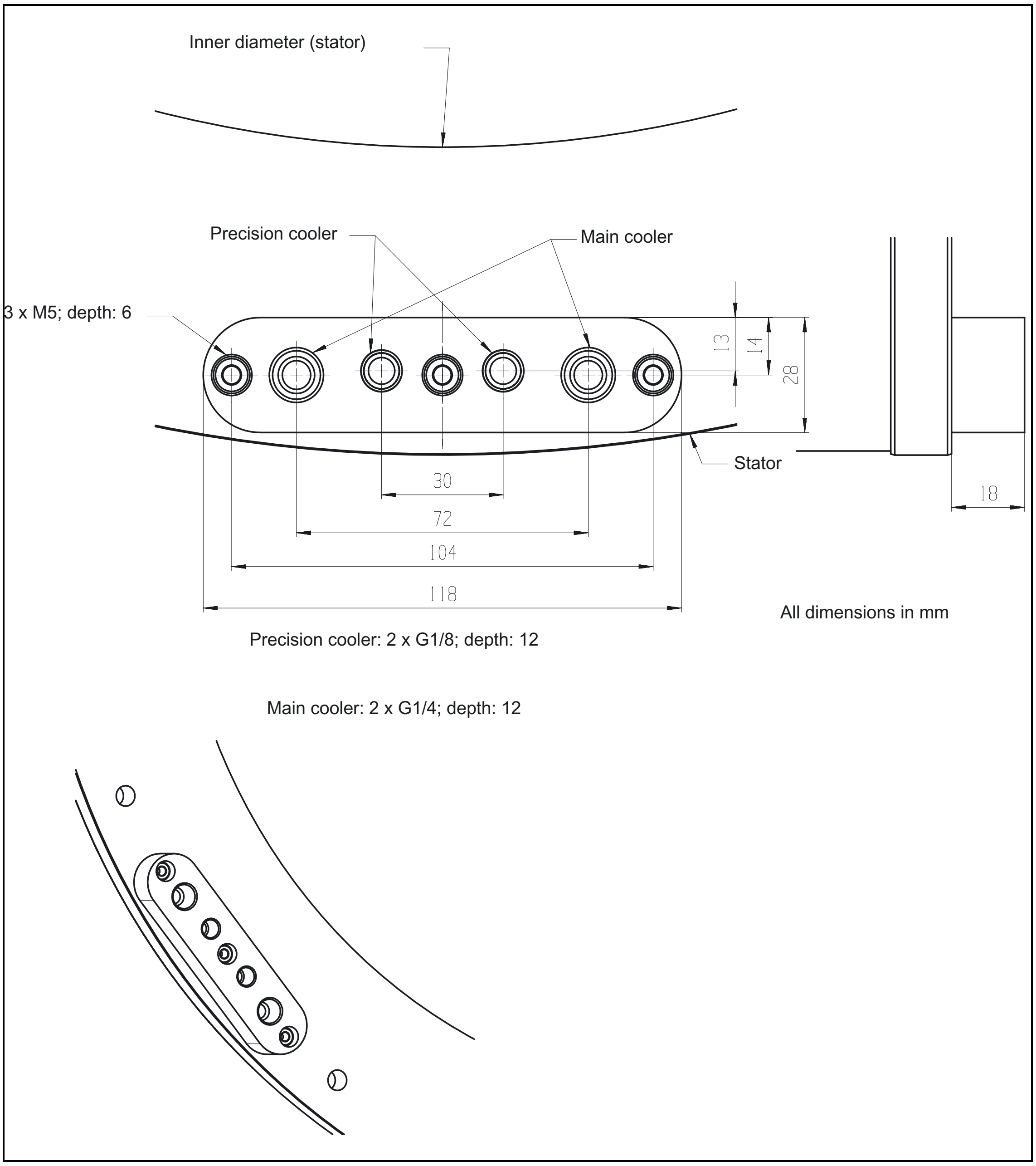


Figure 3-36: Cooling connection plate for 1FW6290

In order to keep the pressure loss low, we recommend that the precision and main cooler are connected in parallel directly in front of the cooler connections. A cooling connection adapter is provided for this purpose (to order, refer to Chapter "Motor rating plate and Order No."; drawing "Cooling connection adapter" refer to Chapter "Motor installation"). This allows the connection to either be made axially or radially (in this case, 1/4” fittings, pipe thread DIN 2999, refer to Figure 3-37 ff).

The pressure losses across the individual cooling components and the piping system must be carefully checked beforehand and compared with the cooling performance of the cooling system (e.g. heat exchanger).

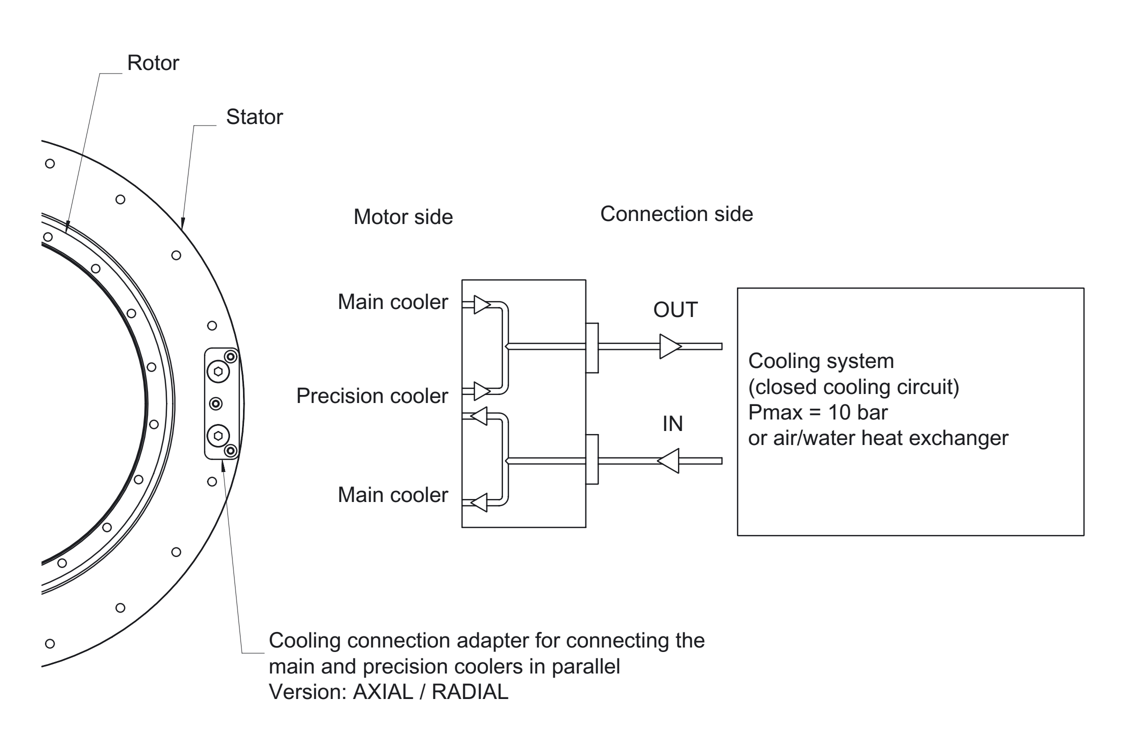


Figure 3-37: Cooling connection adapter for connecting the main cooler and precision coolers in parallel for 1FW6160, 1FW6190, 1FW6230 and 1FW6290

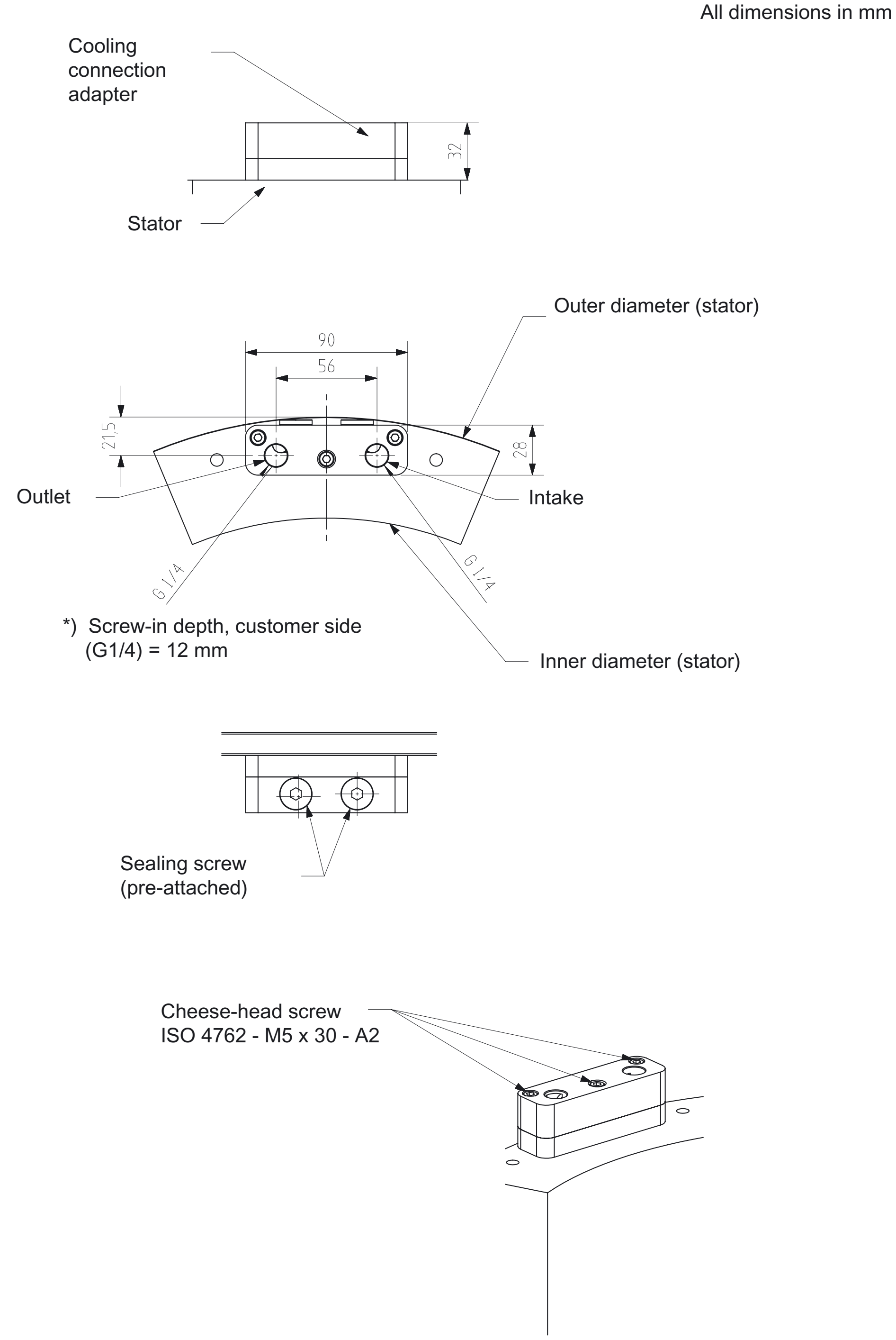


Figure 3-38: Axial cooler connection for 1FW6160, 1FW6190 and 1FW6230

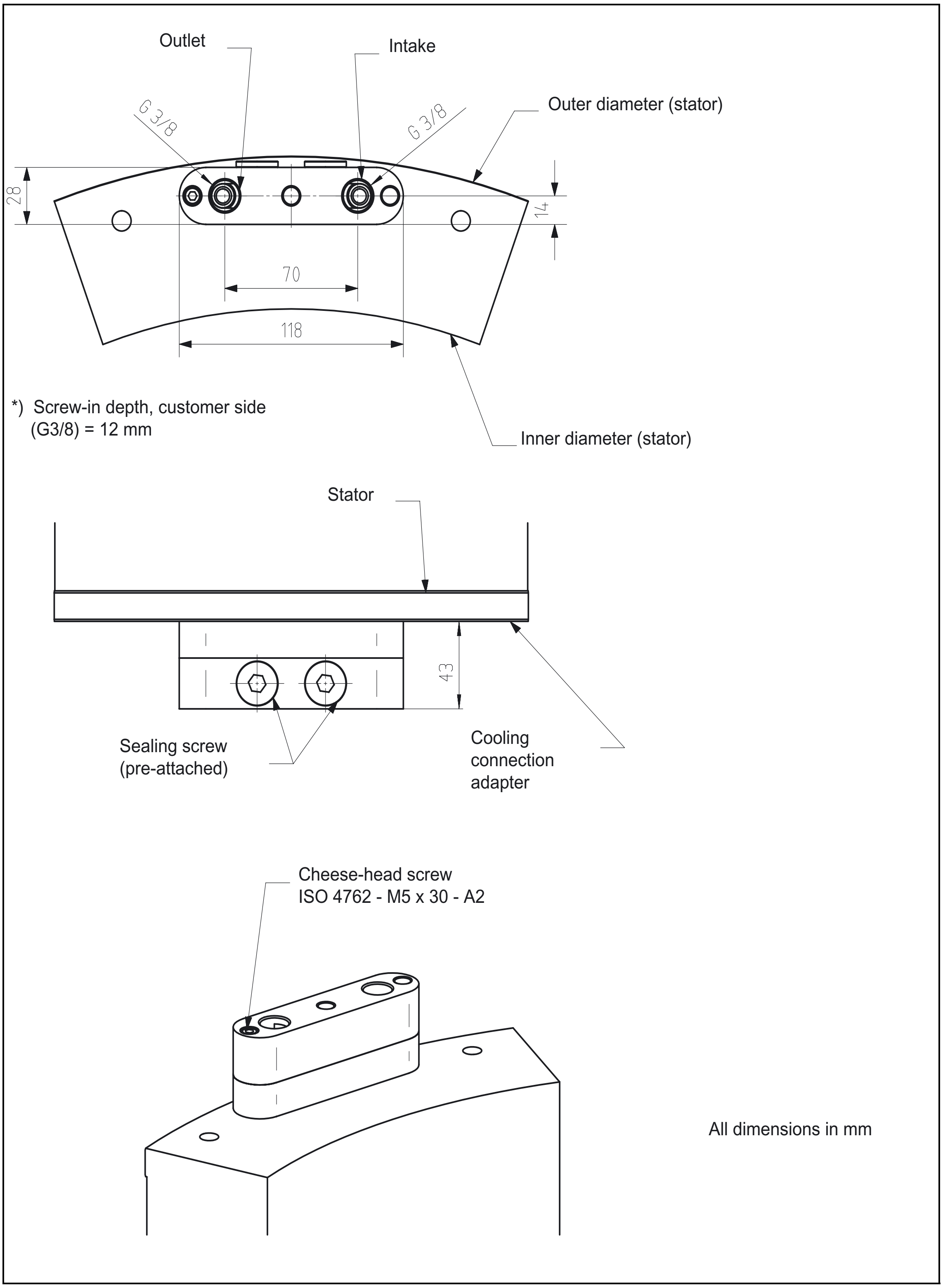


Figure 3-39: Axial cooler connection for 1FW6290

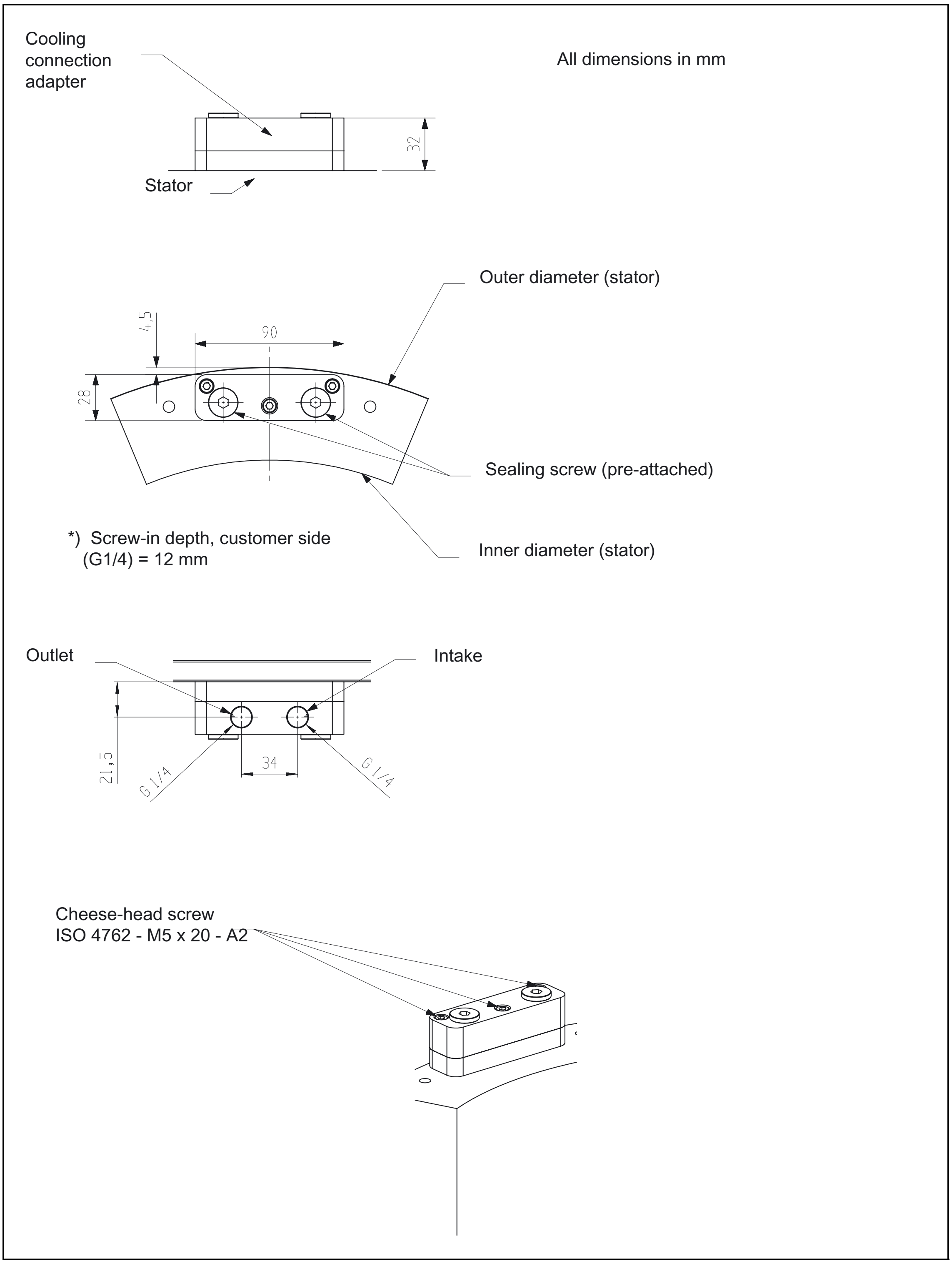


Figure 3-40: Radial cooler connection for 1FW6160, 1FW6190 and 1FW6230

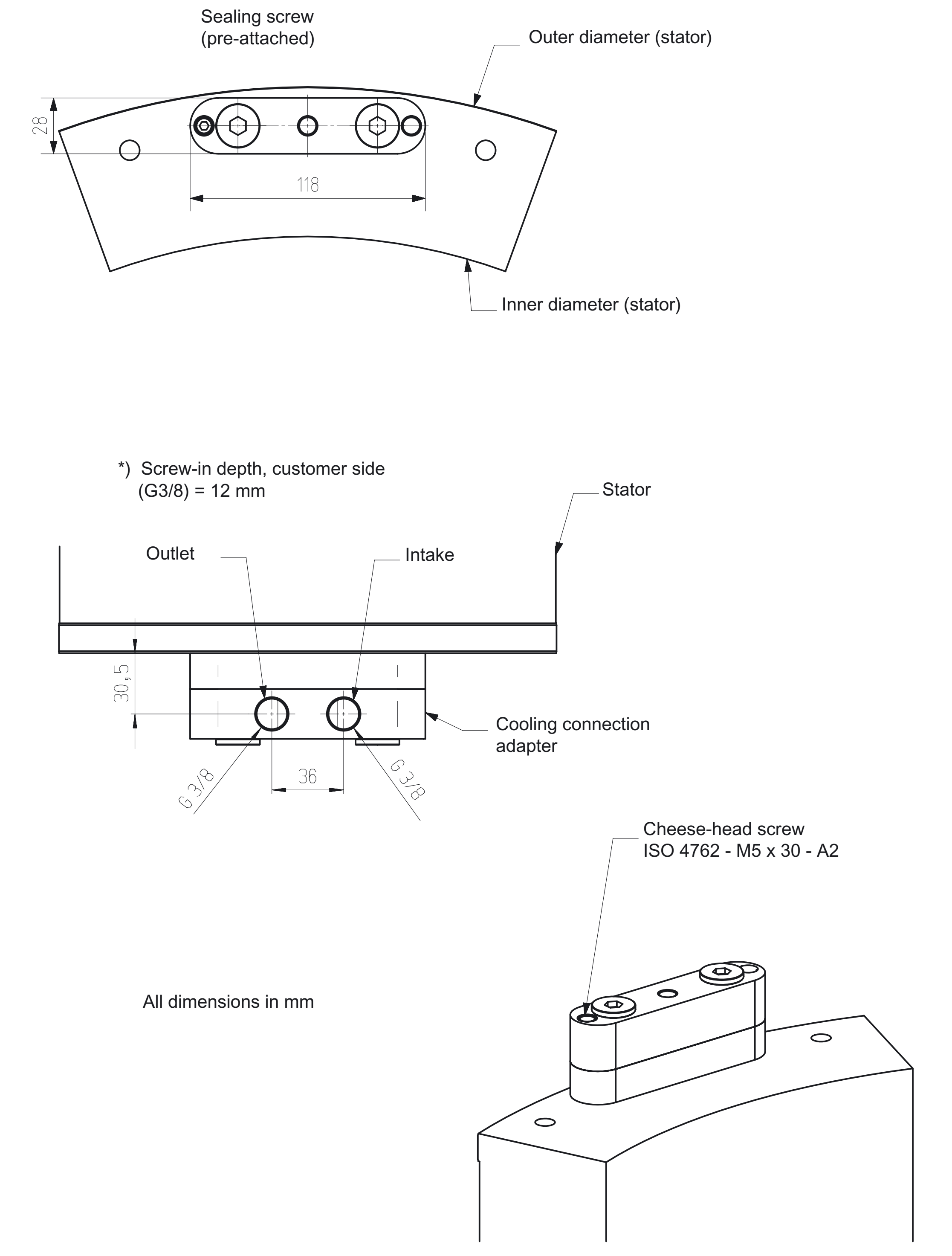


Figure 3-41: Radial cooler connection for 1FW6290

Cooling medium hoses

The cooling medium hoses must have excellent resistance to the cooling medium, must be very flexible and tough (resistant to abrasion). The cooling medium hoses can only be selected after all of the materials and limitations/constraints associated with the cooling system have been clearly identified.

Companies and addresses from where you can order connection parts and accessories for cooling systems are provided in the Appendix.

Notice

We do not guarantee the characteristics and quality of third-party products. Please carefully observe the detailed text in the Foreword.

Commissioning and maintaining the cooling circuits

Before filling the cooling circuits, they must be purged using the cooling medium. The checking and change intervals for the cooling medium should be harmonized with the companies supplying the anti-corrosion agent and the cooling system.

! **Important**

The maximum permissible pressure in the cooling circuit (refer to "Technical features" in Chapter "Features and motor components") may not be exceeded.

3.6 Thermal motor protection

3.6.1 Description of the temperature sensors

Temperature monitoring

1FW6 stators are equipped with the two following temperature monitoring circuits to protect the stator against inadmissibly high thermal stressing as well as to monitor the temperature during the commissioning phase and in operation:

- 2 x Temp–S (1 x PTC 130 °C, i.e. a switching threshold at 130°C and 1 x PTC 150 °C, i.e. a switching threshold at 150°C)
- 1 x Temp–F 1 x KTY 84

Temp–S

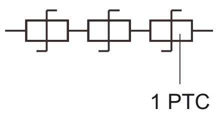
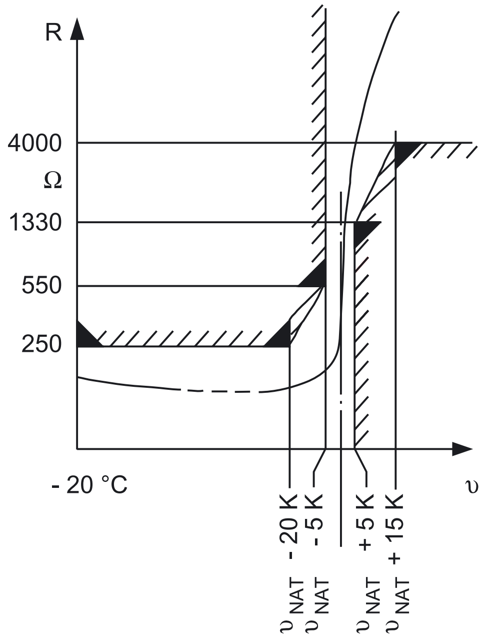
Temperature shutdown circuit comprising PTC temperature sensors (PTC elements).

There is one PTC temperature sensor (PTC element) in each of the three phase windings (U, V and W). The PTC elements are connected in series. The characteristics of the PTC elements are in compliance with DIN VDE 0660 Part 303, DIN 44081 and DIN 44082.

For type B torque motors, the power connection is additionally monitored using a PTC 80°C at the housing. This is connected in series with the PTC 130 °C.

Function:
Every PTC element has a “quasi-switching” characteristic. This means that in the vicinity of the nominal response temperature J_{NAT} (switching threshold), the resistance increases as a step function (the resistance changes suddenly). As a result of the low thermal capacitance and the good thermal contact between the PTC element and the motor winding, the sensor responds quickly to an inadmissibly high stator temperature - therefore ensuring a fast system response.

Table 3-8: Technical data of the PTC thermistor triplet (PTC triplet)

Designation	**Description**
Type	PTC triplet (acc. to DIN 44082- M180)
Response temperature (nominal response temperature J_{NAT})	130 °C ±5 K 150 °C ± 5 K
PTC thermistor resistance (20 °C) at the triplet at T < ϑ_{NAT} – 5 K	min. 60 Ω (3 x 20 Ω) max. 750 Ω
Minimum thermal resistance at the triplet at T = ϑ_{NAT} – 5 K at T = ϑ_{NAT} + 5 K at T = ϑ_{NAT} + 15 K	min. 590 Ω (550 Ω +2 x 20 Ω) max. 1650 Ω (3 x 550 Ω) min. 1370 Ω (1330 Ω +2 x 20 Ω) max. 3990 Ω (3 x 1330 Ω) min. 4040 Ω (4000 Ω +2 x 20 Ω) max. 12000 Ω (3 x 4000 Ω)
Connection via SME9x	Connect the signal cable with connector at SME9x; the signal is evaluated in the drive converter.
Connection via a thermistor motor protection device	Signal cable: Connect conductor bk3 or gn and conductor bk4 or ye at the external 3RN1013-1GW10 tripping unit and evaluate via the PLC.
Application	It is mandatory to connect a PTC triplet to protect the motor against an overtemperature condition. As a minimum, the Temp-S must be connected with a nominal response temperature of 130°C.
Note: The PTC thermistors do not have a linear characteristic and are therefore not suitable to determine the instantaneous temperature.	
Typical characteristic R(J) of a PTC temperature sensor (Caution: Temp-S comprises 3 PTC temperature sensors connected in series!) 	

Temp–F

Temperature sensor circuit comprising one temperature sensor (KTY 84). For torque motors with integrated cooling, there is a type KTY 84 temperature sensor located between two phase windings. For torque motors with cooling jacket there is a type KTY 84 temperature sensor in one phase winding.

Function:
The KTY 84 has a progressive, approximately linear characteristic (temperature – resistance). It has, just like the PTC element of the Temp–S circuit, a low thermal capacitance and also a good thermal contact to the motor winding.

Temp–F is used to monitor the temperature and to possibly provide an alarm before an imminent "immediate" drive shutdown by Temp–S.

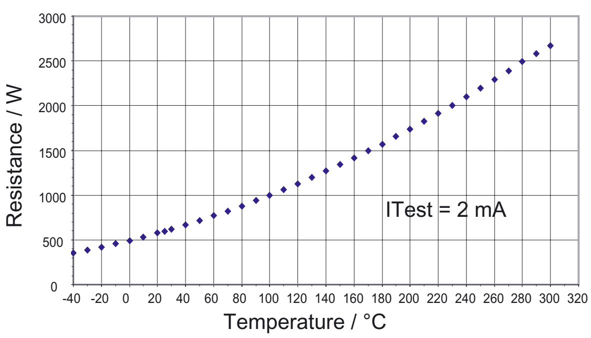
Warning

It is not permissible to evaluate Temp–F to protect the motor.

Using Temp-F, the temperature is only measured between two phase windings or in just one phase winding. If an overtemperature condition occurs in the phase winding that is not monitored, then this cannot be immediately displayed and evaluated. Further, Temp-F has a slow characteristic that is not suitable for a fast shutdown (trip).

Different current magnitudes - and therefore different associated thermal loads - of the individual phase windings occur if the motor is either stationary (zero speed) or rotates very slowly but is still generating a torque.

Table 3-9: Technical data of the KTY 84 PTC thermistor

Designation	Description
Type	KTY 84
Transfer range	- 40 °C ... + 300 °C
Resistance when cold (20 °C)	Approx. 580 Ω
Resistance when hot (100 °C)	Approx. 1000 Ω
Connection via SME9x	Connect the signal cable with connector at SME9x; the signal is evaluated in the drive converter.
Connection via a multimeter with the appropriate voltage rating	Signal cable: For reasons associated with protective separation (according to VDE 0160 / EN 50178) conductor bk1 or wh and conductor bk2 or bn may not be directly evaluated via SIMODRIVE. One possibility is to evaluate the signal using a multimeter with the appropriate voltage rating (V > 1000 V)
Application	Temperature monitoring to determine the motor utilization:
Temperature characteristic	

3.6.2 Evaluating the temperature sensors to protect the motor

Temp–S

Temp–S is used to reliably protect the motor against overheating.

If Temp-S responds, then the drive converter must be quickly shut down to stop the supply to the stator (= additional thermal load). This thermal load is caused by the current magnitude, specified by the closed-loop control (setpoint(s)) and can result in the stator being destroyed.

There are two possibilities of evaluating Temp–S:

1. Evaluation via the SME9x and the drive converter. In this case, only the PTC 130 °C is evaluated. An internal logic circuit of the SME9x takes into account the short thermal time constant of the stator winding so that if the overtemperature condition or fault remains (max. 2 seconds), the drive converter switches the drive into a no-current condition.

Note

Please observe the following when parameterizing the machine data:

- MD1607 (shutdown limit, motor temperature) must be 155 °C, i.e. it is not permissible that this parameter is changed.
- MD1602 (pre-alarm threshold) and MD1603 (timer stage, motor temperature alarm) can be changed in-line with the particular application. However, MD1602 (pre-alarm threshold) should not be greater than the shutdown temperature of the PTC temperature sensor.

  There is a direct interrelationship between MD1602 and MD1603: If, for example, a lower temperature value is entered for MD1602, then a longer time may be entered into MD1603.

---

2. Evaluation via PLC and connection via the thermistor motor protection device:

   a) Only one PTC is evaluated, if e.g. the drive system only has one evaluation channel.

      In this particular case, PTC 130 °C must be evaluated. As a result of the short thermal time constant of the stator windings, the response time of the drive system should always be implemented so that the stator is always in a no-current condition 1 second after the shutdown (trip) signal of the PTC 130 °C.

   b) Both PTC elements are evaluated:
      In this case, the PTC 130 °C is used to issue an alarm signal. If the temperature continues to increase, when the response temperature of the PTC 150 °C is reached, it responds and the stator must be immediately brought into a no-current condition.

Temp–F

Temp–F supplies an analog signal that is proportional to the temperature and when the current load of the three phase windings is symmetrical, provides information about the average motor temperature.

The motor temperature can be optionally displayed using the signal from Temp–F. In this case, depending on the motor type and application, from a temperature of 100 ... 110 °C and higher, an alarm signal should be output that reduces the torque demanded from the drive (reduces the current magnitude).

Note

Temperature sensor (Temp–F) only evaluates the winding temperature between two phases or in one stator phase. However, the phases in the synchronous motor are loaded to different degrees depending on the operating mode. In the worst case, this would mean that the phases that are not measured have the highest temperatures.

3.6.3 Connecting-up the temperature monitoring circuits

Temperature sensor connection via SME9x

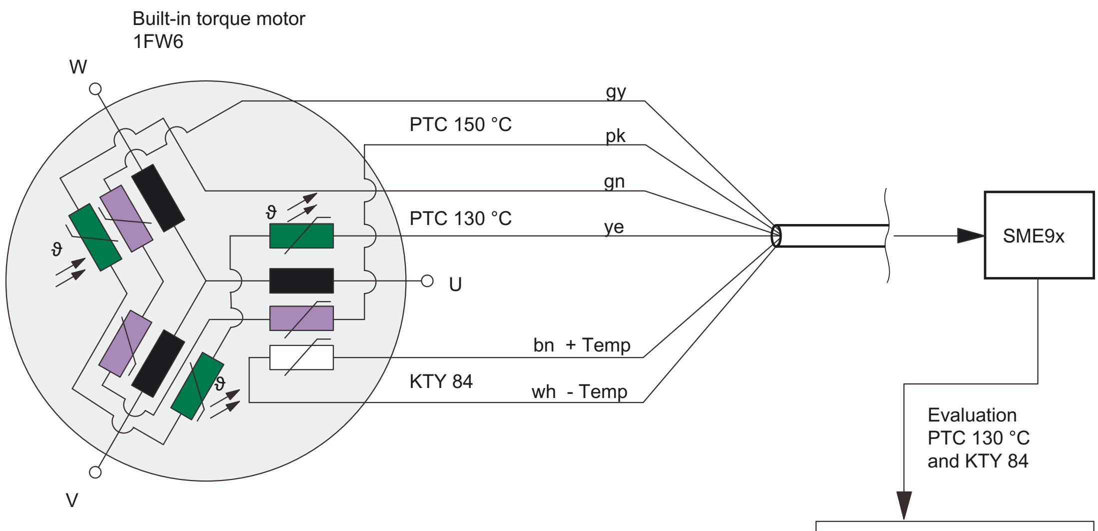
Connect the signal cable with a connector to the SME9x (**S**ensor **M**odule **E**xternal); its output is connected to the drive converter. Also refer to Figure 3-10 Chapter "System integration" and the following connection overview.

The SME9x is used to
- protect the motor
- evaluate the actual operating temperature,
- connect the motor sensors close to the motor, and
- connect the WMS (angular measuring system) close to the motor

The thermistor motor protection device 3RN1013-1GW10 that was previously required to connect the PTC sensors and the external measuring device to evaluate the KTY 84 sensor is no longer required.

Additional information on the SME9x is provided in the Sensor Module External SME9x Manual that you can order from your local Siemens office.

Connection overview



Note:
- PTC: Characteristic acc. to DIN VDE 0660 Part 303, DIN 44081, DIN 44082
- The shutdown circuit via the SME box must be carefully checked that it correctly shuts down before the motor is commissioned!

Figure 3-42: Connection overview with SME9x

Temperature sensor connection via the thermistor motor protection device

From the terminal box use the signal cable to connect a MOTION-CONNECT cable.

Temp–S

If only a PTC is evaluated, the Temp–S 130 °C must be used. This should be connected to a thermistor motor protection tripping device. The thermistor motor protection tripping device, which is not included in the scope of supply, must be implemented so that there is protective separation.

The thermistor protection device 3RN1013-1GW10 is available for this purpose (also refer to Figure 3-43 on Page 100).

Up two PTC triplets (i.e. two stators) can be evaluated at each sensor input at the thermistor motor protection tripping device.

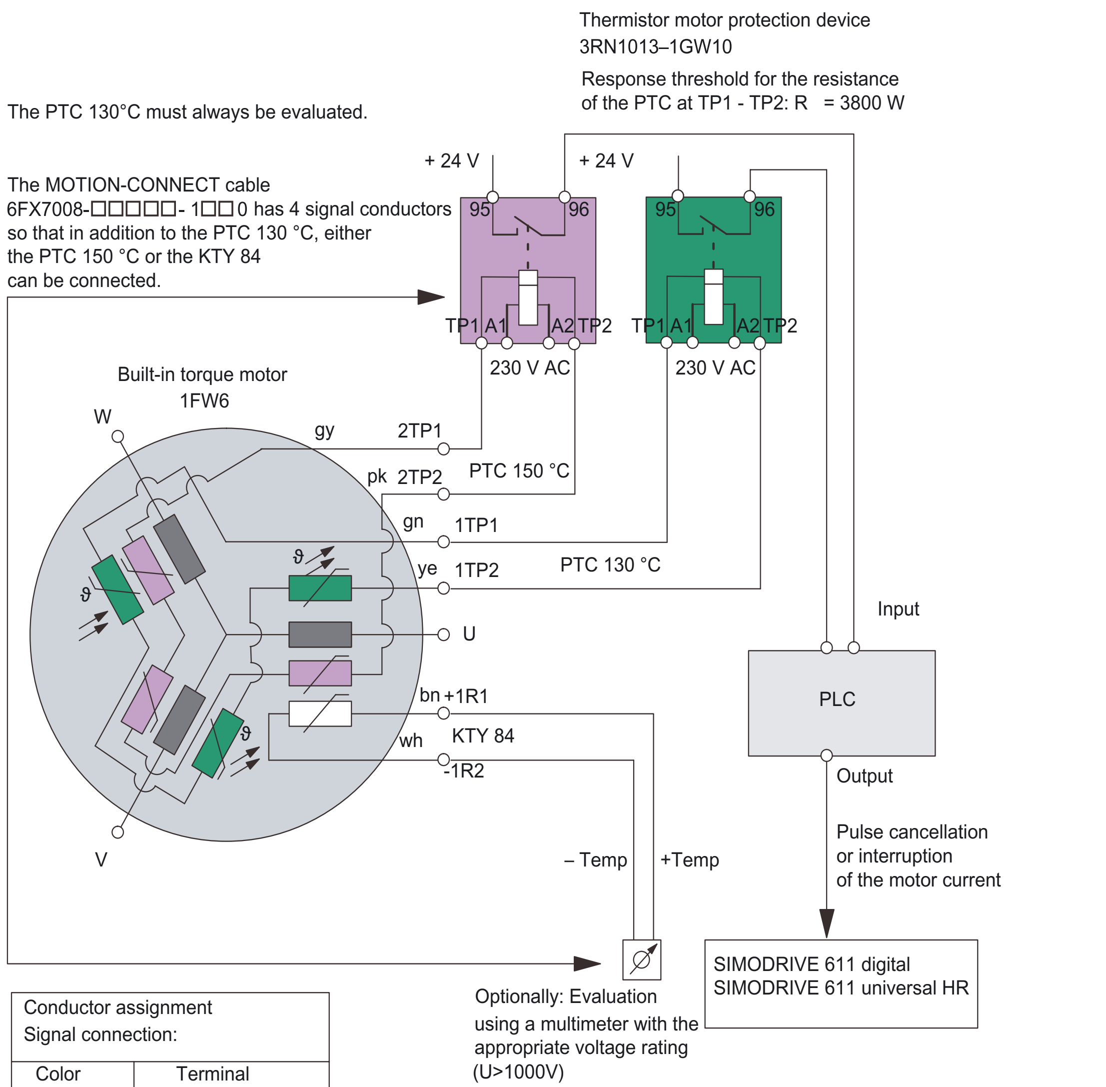
Temp–F

For reasons of protective separation (in compliance with VDE 0160 / EN 50178) Temp–F may not be directly evaluated at SIMODRIVE drive converters.

Danger

The Temp–S and Temp–F circuits do not have "protective separation" in accordance with VDE 0160 EN 50178 – neither with respect to one another nor to the power circuits.

Connection overview



Conductor assignment
Signal connection:

Color	Terminal
bk1 or wh	- 1R2: KTY (–Temp)
bk2 or bn	+1R1: KTY (+Temp)
bk3 or gn	1TP1: PTC 130 °C
bk4 or ye	1TP2: PTC 130 °C
bk5 or gy	2TP1: PTC 150 °C
bk6 or pk	2TP2: PTC 150 °C

Note:

- KTY 84: Observe the polarity!
  - wh —> - Temp
  - bn —> + Temp
- PTC: Characteristic acc. to DIN VDE 0660 Part 303, DIN 44081, DIN 44082
- PLC: The shutdown circuit via the PLC must be carefully checked that it correctly shuts down before the motor is commissioned!

If only the PTC 130 °C is evaluated, then the stator must be in a no-current condition a maximum of 1 second after the shutdown signal.

Figure 3-43: Connection overview with thermistor motor protection devices

3.7 Cooling

The power loss generated in the stator winding must be dissipated using the cooling. The machinery construction OEM must connect the cooling duct, provided for cooling, to a cooling circuit of a cooling system. For characteristics showing the temperature rise and the pressure drop of the cooling medium between the intake and outlet of the cooler as a function of the flow rate refer to Chapter "Technical data and characteristics".

For certain operating states, e.g. at high speeds and for S1 duty, an additional temperature rise of the rotor can be expected as a result of iron losses. The rated motor torques specified in the data sheets (refer to Chapter "Technical data and characteristics") apply for operation with water cooling with an intake temperature of 35 °C and a rotor flange temperature of max. 60 °C. In order to comply with these conditions, it may be necessary to apply measures to cool the rotor.

If liquid cooling is not used, in continuous operation the motor may only provide a significantly reduced continuous torque ($M \ll M_N$). This depends on the size, power loss, radiating surface, convection and installation conditions at the machine. The maximum motor torque can be utilized.

Note

Depending on the particular load and operating mode, the average stator and rotor temperature can be up to 120°C. The thermal impact on the machine assembly and the radial and axial thermal expansion of the motor must be taken into account in the mechanical design.

Warning

Without liquid cooling:
Significantly lower continuous torque (depending on the thermal relationship with respect to the surrounding mechanical assembly) as well as a significant temperature increase of the mechanical assembly.

- therefore use liquid cooling.
- for axes that are to be operated without liquid cooling, the continuous motor torques must be reduced and the thermo-elastic deformation of the machine construction (stress and tension as a result of expansion) must be taken into consideration when designing/dimensioning the drive and the mechanical assembly.

Motors with integrated cooling should not be operated without liquid cooling.

Carefully observe Chapter "CSA/UL certification" in order not to lose this certification for certified motors.

Warning

While the torque motor is operational, the maximum temperature of the rotor may not exceed 120°C as this could de-magnetize the permanent magnets. This must be ensured when the system is commissioned for the first time by making the appropriate checks.

We would like to make special reference to non-uniform current loads at standstill or operation with short cyclic rotary motion as in this case especially high temperatures can occur.

3.7.1 Cooling circuit

We recommend that the cooling circuits are implemented as closed systems in order to avoid oxidation that can promote corrosion. The maximum permissible pressure is 10 bar.

Note

We recommend that the cooling circuits of machines are not used to cool the motors: Blockages can occur due to dirt and long-term deposits!
The maximum standstill times of the cooling circuit must be carefully observed (refer to the data sheets of the cooling medium manufacturer).

Cooling media

The customer provides the cooling medium. Water with an anti-corrosion agent should be preferably used as cooling medium.

If non-treated water is used, then as a result of lime deposits, algae and the formation of mould and corrosion, significant damage and disturbances can occur, e.g.

- deterioration of the thermal transfer
- higher pressure losses due to restrictions (reduced cross-sections)
- valves, heat exchanger and cooling ducts can become blocked

This is the reason that water as cooling medium must contain an anti-corrosion agent that also reliably prevents deposits and corrosion even under extreme conditions. Further, we recommend a closed cooling circuit (equalization chamber) to reliably avoid algae.

The cooling medium must be pre-cleaned or filtered in order to prevent the cooling circuit becoming blocked. It is not permissible that ice forms!

Note

The maximum permissible particle size in the cooling medium is 100 µm.

The water that is used as basis for the cooling medium must fulfill, as a minimum the following requirements:

- concentration of chlorides: $c < 100$ mg/l
- concentration of sulfates: $c < 100$ mg/l
- $6.5 \leq$ ph value ≤ 9.5

Please contact the manufacturer of the anti-corrosion agent for additional requirements!

Warning

It is not permissible to use oil as cooling medium for motors with integrated cooling. The reason for this are incompatibilities between materials that can destroy the cooling medium hoses inside the motor.

The anti-corrosion agent must fulfill the following requirements:

- ethylene glycol is the basis (also "Ethandiol").
- water and anti-corrosion agents may not separate.
- the freezing point of the water used must be reduced to at least –5 °C.
- the anti-corrosion agent used must be compatible with the fittings and cooling medium hoses being used as well as the materials of the motor cooler listed in the following table.

Discuss and coordinate these requirements - especially the material compatibility - with the cooling system manufacturer and the anti-corrosion agent manufacturer! Refer to the Appendix for recommended manufacturers.

Table 3-10: Materials used in the cooling circuits of torque motors (without the material of the connecting parts)

Cooler	Cooling jacket	Integrated cooling (main cooler)	Integrated cooling (precision cooler)	Cooling connection adapter
Materials	Aluminum + Viton seal	V2A steel + copper + brass + Viton seal + silicone hose	V2A steel + copper + brass + Viton seal + silicone hose	Brass, chemically nickel-plated

$$Q = \rho \cdot c_p \cdot \dot{V} \cdot \Delta T$$

Average specific density: ρ in kg/m^3
Average specific thermal capacitance: c_p in J/(kg K)
Temperature rise with respect to the intake temperature: ΔT in K
Flow rate: $\dot{V}$ in m^3/s

Figure 3-44: Formula to calculate the thermal power that the cooler can dissipate

Cooling-medium intake temperature

The intake temperatures should be selected so that no moisture condensation forms on the surface of the motor: Moisture condensation does not damage the torque motor itself but can lead to corrosion in the machine.

$T_{cool} \geq T_{ambient} - 2\ K$

The motors are designed, in accordance with DIN EN 60034–1 for operation with a cooling-medium temperature of up to 35°C and where all of the motor data are maintained. If the intake temperature is different than that specified, then the continuous torque changes according to the following diagram.

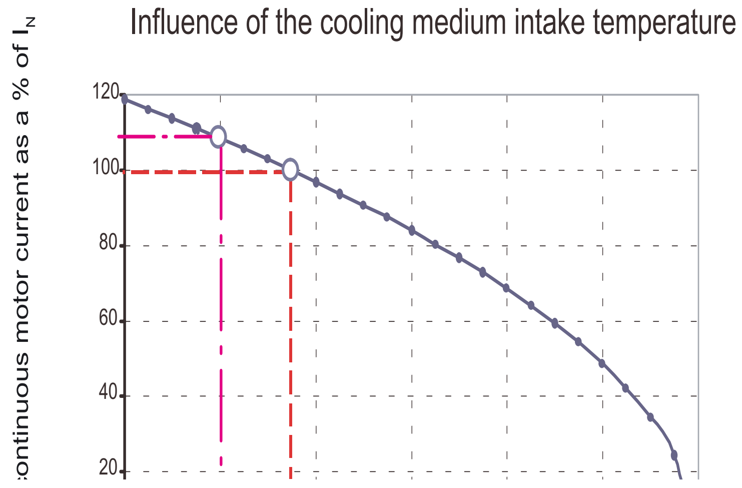


Figure 3-45: Continuous motor current as a function of the intake temperature of the water cooling in the main cooler when neglecting the rotor losses

Carefully observe Chapter "CSA/UL certification" in order that this certification remains valid for certified motors.

Cooling system

A cooling system (i.e. heat exchanger) must be used in order to guarantee a cooling medium intake temperature of 35 °C. It is possible to operate several motors from a single cooling system. The cooling system is not part of the scope of supply.

The cooling power is calculated from the sum of the power losses of the connected motors. The pump power rating must be adapted corresponding to the specified flow rate and the pressure loss across the cooling circuit.

Companies and addresses of cooling system manufacturers are listed in the Appendix.

Dimensioning the cooling system

The power loss occurring in the motor under continuous operating conditions causes a flow of thermal energy. A large proportion of this thermal energy flow is dissipated through the cooling medium of the cooling system and a lower proportion through the surrounding mechanical assembly. The cooling power of the cooling equipment in the cooling system must be designed so that it can dissipate, as a minimum, 85 - 90 % of the power loss that occurs. For several motors, this applies to the sum of the individual power losses.

In continuous operation, the motor may only be loaded so that the rms torque M_{rms} does not exceed the magnitude of the continuous torque M_N. As a consequence of this, the rms power loss may only reach as a maximum the value of the continuous power loss.

$$\frac{P_V}{P_{V,N}} = \left(\frac{M_{rms}}{M_N}\right)^2$$

If the magnitude of the actual rms losses cannot be predicted or the calculation appears to be too complex, then as an equivalent, the sum of the continuous power losses (values in a table) of all of the motors being used can be used to calculate the required (theoretical) cooling power.
In this case, as a result of the deviation to the actual rms power loss, it is possible that the cooling system will be slightly over-dimensioned.

The cooling system must have an adequate performance in order to provide the required cooling medium pressure at the maximum specified flow rate.

3.8 Short-time duty S2 and intermittent duty S3

3.8.1 Short-time duty S2

For short-time duty S2, the load time is so short that the final thermal state is not reached. The subsequent no-current interval is so long that the motor practically never completely cools down.

Notice

An excessively high load can destroy the motor.
The load may never exceed the value I_{MAX} specified in Chapter "Technical data"!

The motor may only be operated with a current $I_N < I \leq I_{MAX}$ for a limited time $t \leq t_{MAX}$. Time t_{MAX} can be determined from the logarithmic formula

$$t_{MAX} = t_{TH} \bullet ln\left[\frac{\nu}{\nu - 1}\right]$$

with $\nu = (I / I_N)^2$ and the thermal time constant t_{TH}.

The thermal time constants, the maximum currents and the rated currents of the motors can be taken from Chapter "Technical data and characteristics".

Note

The equation shown above is valid under the assumption that the initial temperature of the motor corresponds to the intake temperature of the water cooling T_{INTAKE}!

Example

A 1FW6190-xxx15-2Jxx motor is to be operated with the maximum current from the cold state.

- I_{MAX} = 47 A, I_N = 26 A; this results in ν = 3.268
- t_{TH} = 180 s

$$t_{MAX} = 180\ s \bullet ln\left[\frac{3,268}{3,268 - 1}\right]$$

$$t_{MAX} \approx 66\ s$$

The motor may be operated for a maximum of 66 s with the maximum current.

3.8.2 Intermittent duty S3

For intermittent duty S3, the load times t_B with constant current alternate periodically with standstill times t_S where no current flows. The motor temperature increases during the load time and cools down again at standstill (no-current). After a sufficiently high number of load duty cycles with duty cycle duration $t_{duty\ cycle} = t_B + t_S$, the temperature characteristic moves between a constant maximum value T_O and a constant lowest (minimum) value T_U, refer to the following diagram.

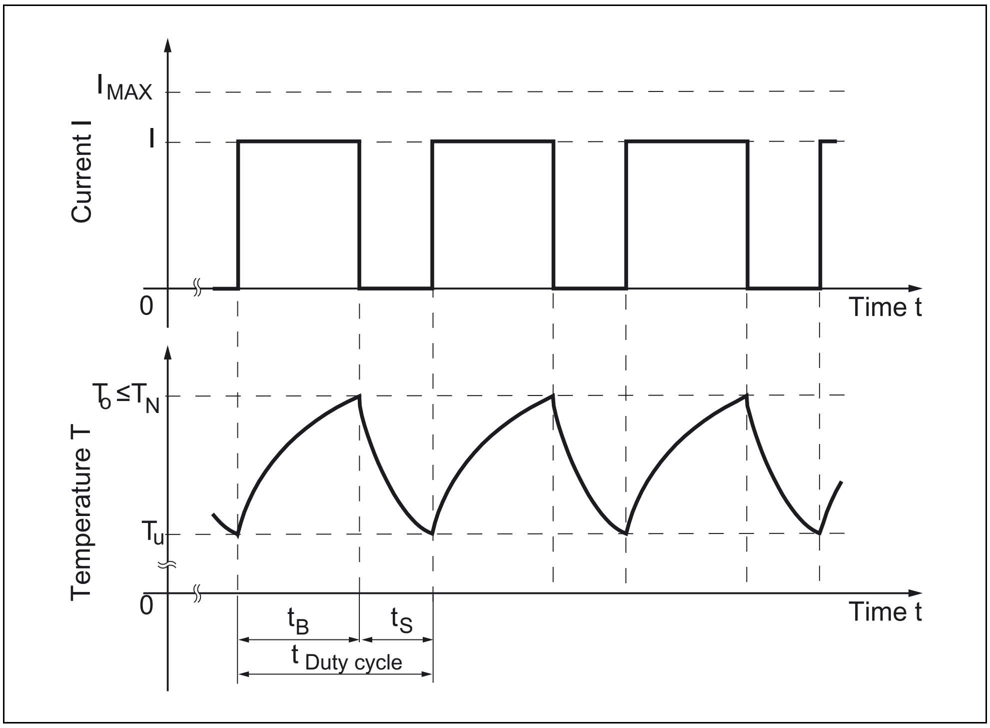


Figure 3-46: Current and temperature characteristic for intermittent duty S3

For currents $I_N < I \leq I_{MAX}$ it is not permissible that the continuous rms current exceeds the rated current, also refer to Chapter "Selecting torque motors".

$$I_{rms} = \sqrt{\frac{(I^2 \cdot t_B)}{t_{Duty\ cycle}}} = I \cdot \sqrt{\frac{t_B}{t_{Duty\ cycle}}} \leq IN$$

In this case, the duty cycle should not be longer than 10 % of the thermal time constant t_{TH} . If a longer load duty cycle is required, then please contact your local Siemens office.

3.9 Operating several motors in parallel

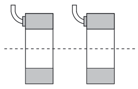
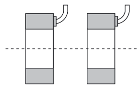
When certain prerequisites are met, built-in torque motors can be operated in parallel on one axis and fed from a common drive converter. For the appropriate drawings refer to the end of this Chapter.

Note

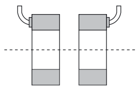
Only torque motors having the same frame size and identical winding design may be connected in parallel. In this case, the direction of the cable outlets is of no significance; i.e. the Order Nos. (MLFB) of the motors do not have to be identical.

For questions regarding the optimum engineering/design of drive systems with torque motors connected in parallel, please contact your local Siemens office.

The following motor arrangements are possible when connecting two motors in parallel:

a) The tandem arrangement  or 

The motor cable outlets are located on the same side. When using standard motors, both of the motors have the same direction of rotation.

b) The Janus arrangement 

The cable outlets of the motors are located on opposite sides. When using standard motors the stoker (as described in the following) must be disconnected so that both motors rotate in the same direction.

The term "stoker" is the second motor in an axis that does not have the same direction of rotation as the first motor ("master") regarding phases U V W. In order that this stoker has the same direction of rotation phases V and W must be interchanged when the stoker is connected-up.

Table 3-11: Power connection for parallel operation

Drive converter	Master	Stoker	Stoker
-	-	**Tandem arrangement**	**Janus arrangement**
U	U	U	U
V	V	V	W
W	W	W	V

The following must be carefully noted when connecting motors in parallel to power one axis:

- only the same motor types are suitable for parallel operation.
- the phase positions of the EMFs of the parallel motors must be identical and the commutating angle must be precisely set.
- the markings (notch and/or fitting bore) at the stator/rotor of the particular motor must be precisely aligned. In this case the position of the motors with respect to one another can be freely selected.

In this case, the machinery construction OEM must provide, in the surrounding mechanical assembly, a possibility of mechanically adjusting the angular position (e.g. using an intermediate flange with elongated holes) - either at a stator or at a rotor. An adjustment angle of +/-0.5° mechanical must be provided to optimally set the angular position.

Caution

If the angular position is not correctly adjusted, in continuous operation at the rated load, one of the two parallel motors could be thermally overloaded. This is the reason that it may be necessary to reduce the torque as a function of the load in order to avoid the PTCs tripping the drive.

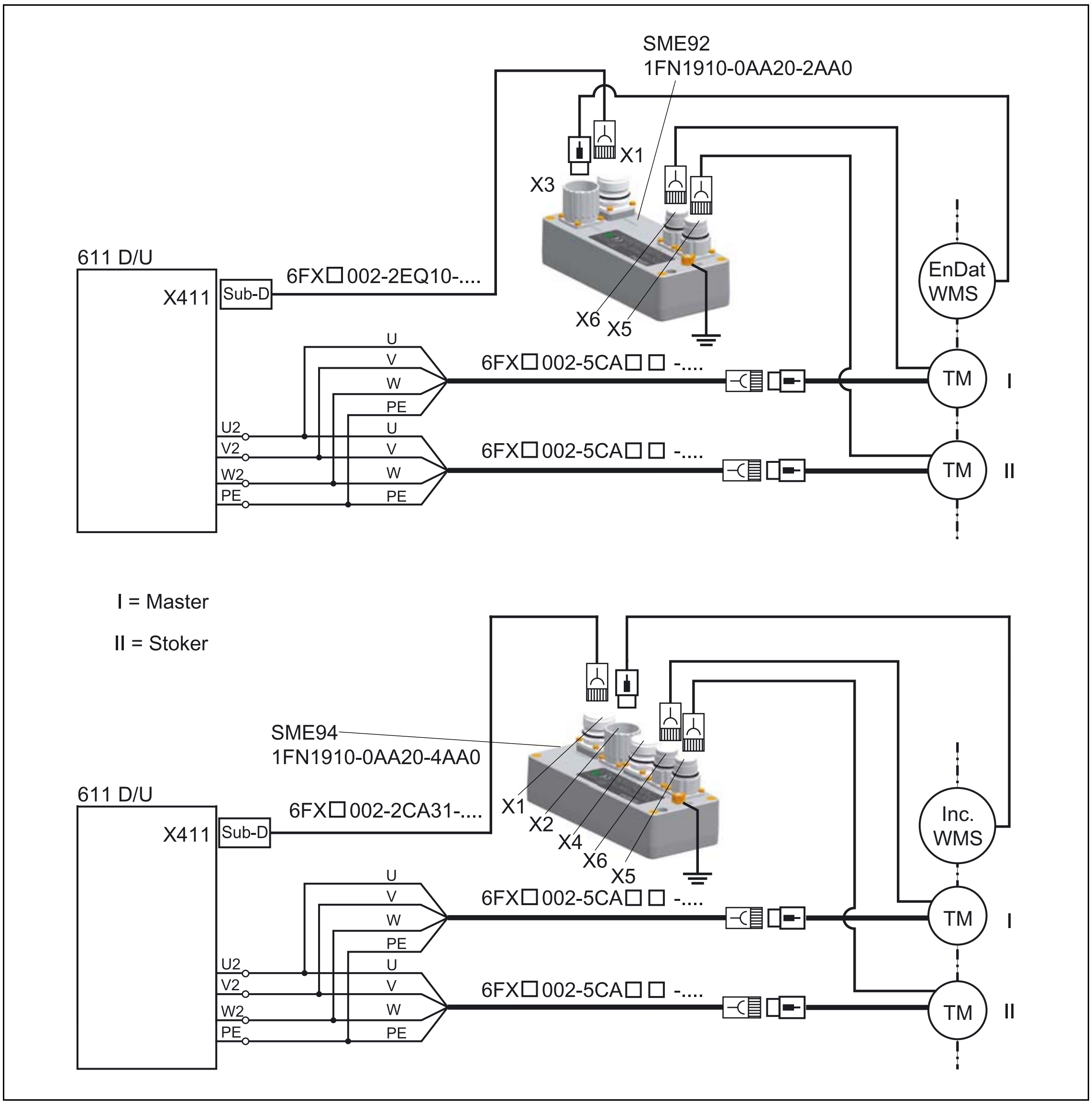


Figure 3-47: Connection diagram of two torque motors connected in parallel (tandem arrangement) with SME9x

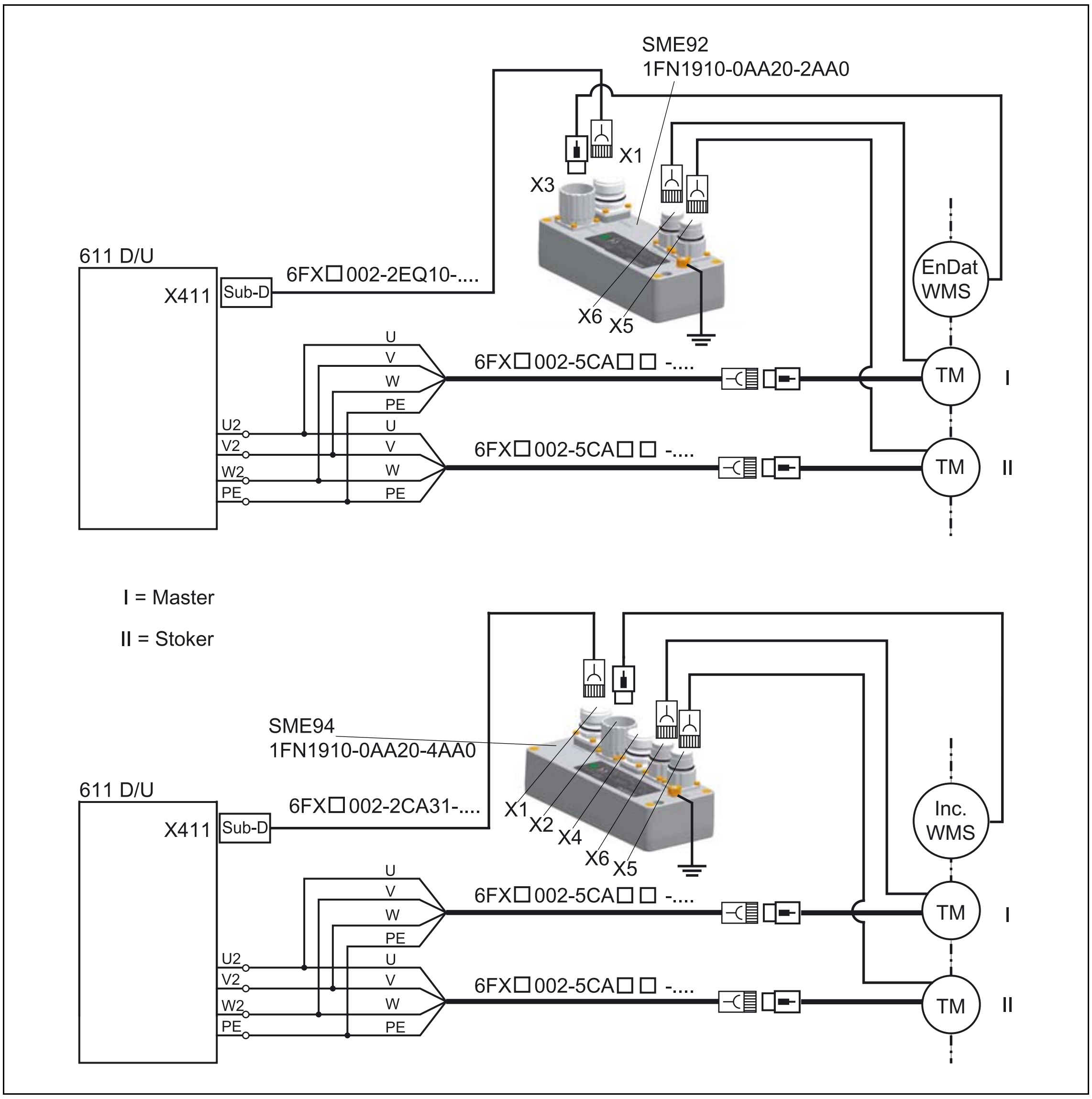


Figure 3-48: Connection diagram of two torque motors connected in parallel (Janus arrangement) with SME9x

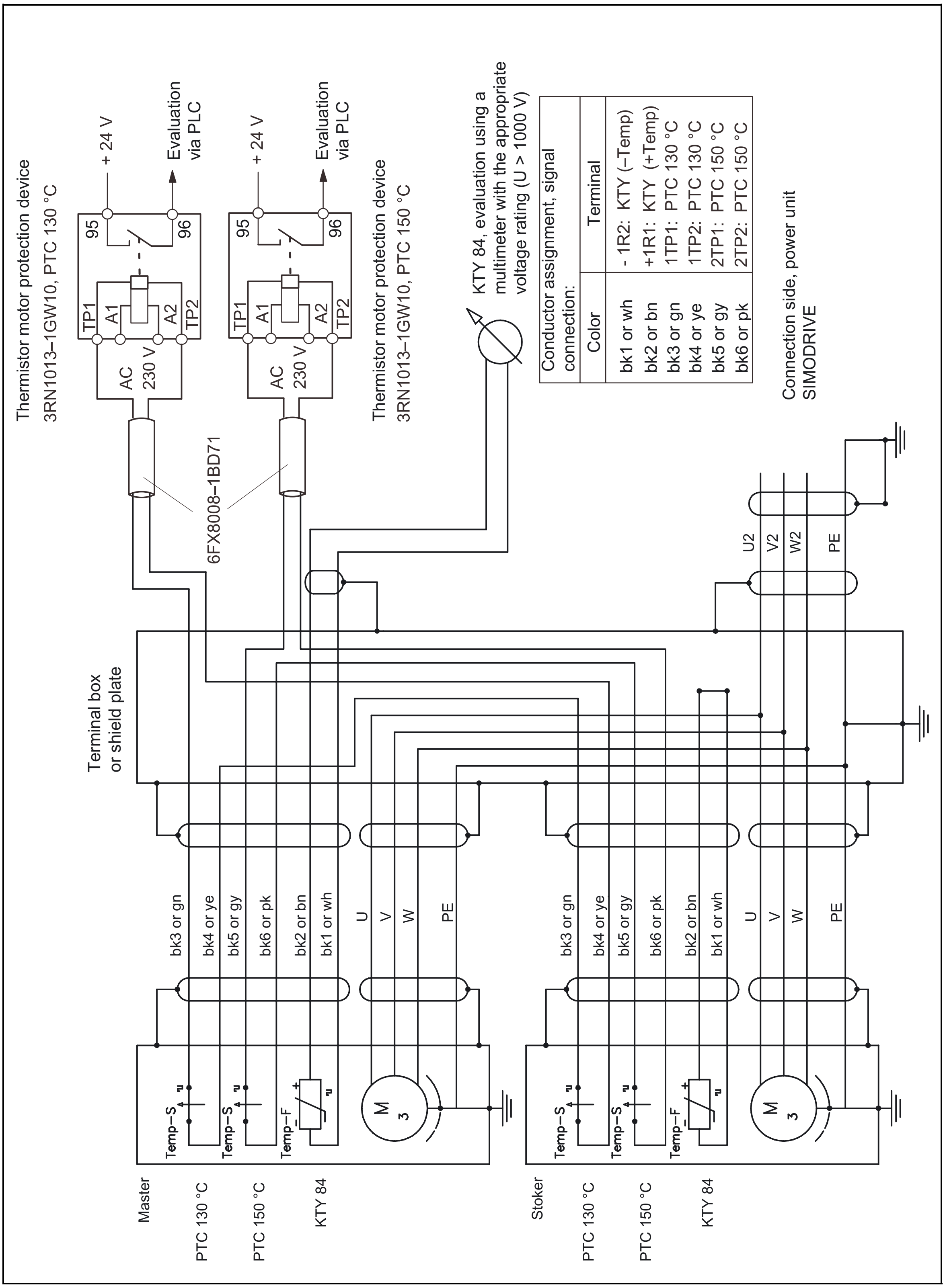


Figure 3-49: Connection diagram of two torque motors connected in parallel (tandem arrangement) where PTC 130 °C and PTC 150 °C are connected through the thermistor motor protection device

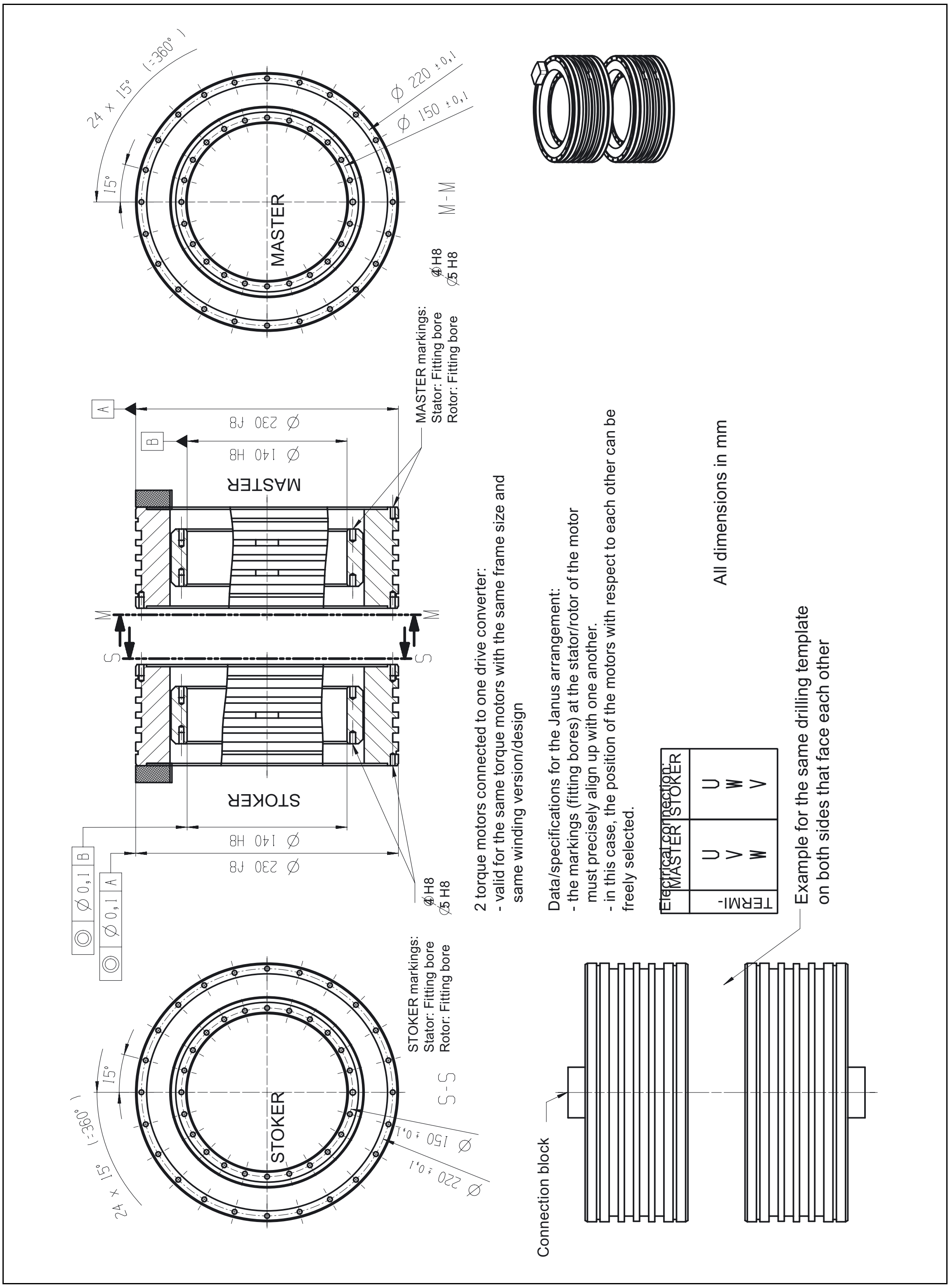


Figure 3-50: 1FW6090-0x... Janus arrangement

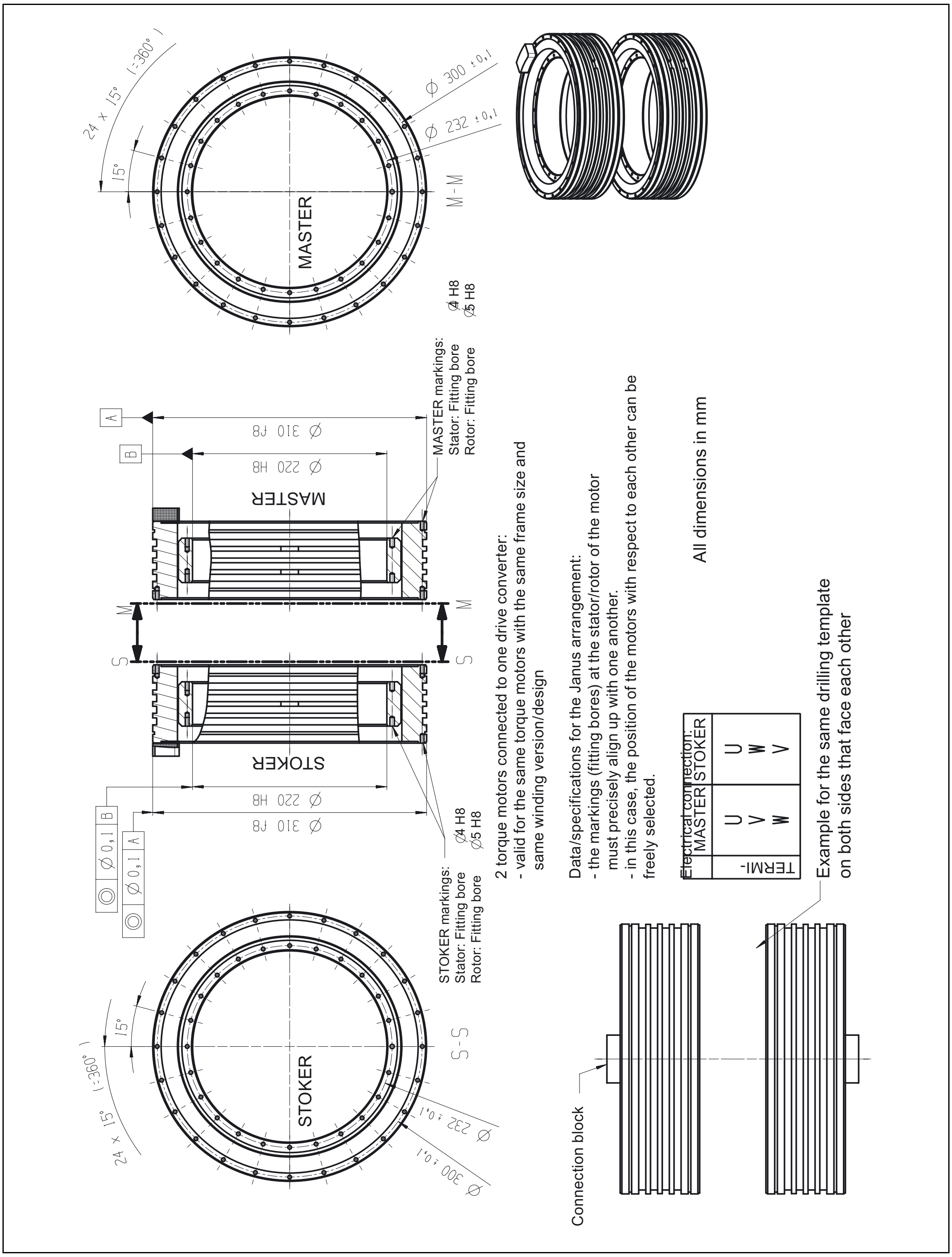


Figure 3-51: 1FW6130-0x... Janus arrangement

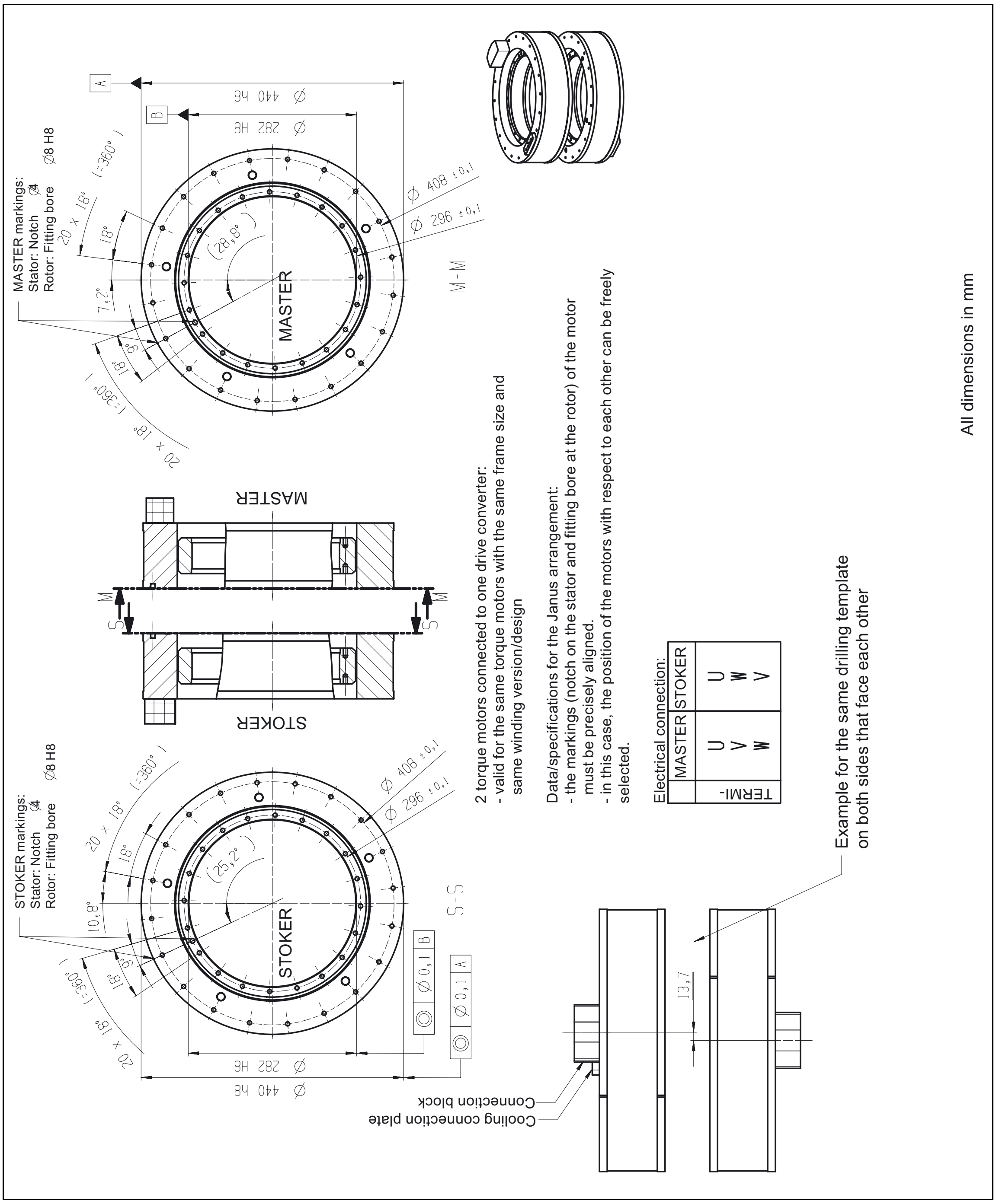


Figure 3-52: 1FW6160-0x... Janus arrangement

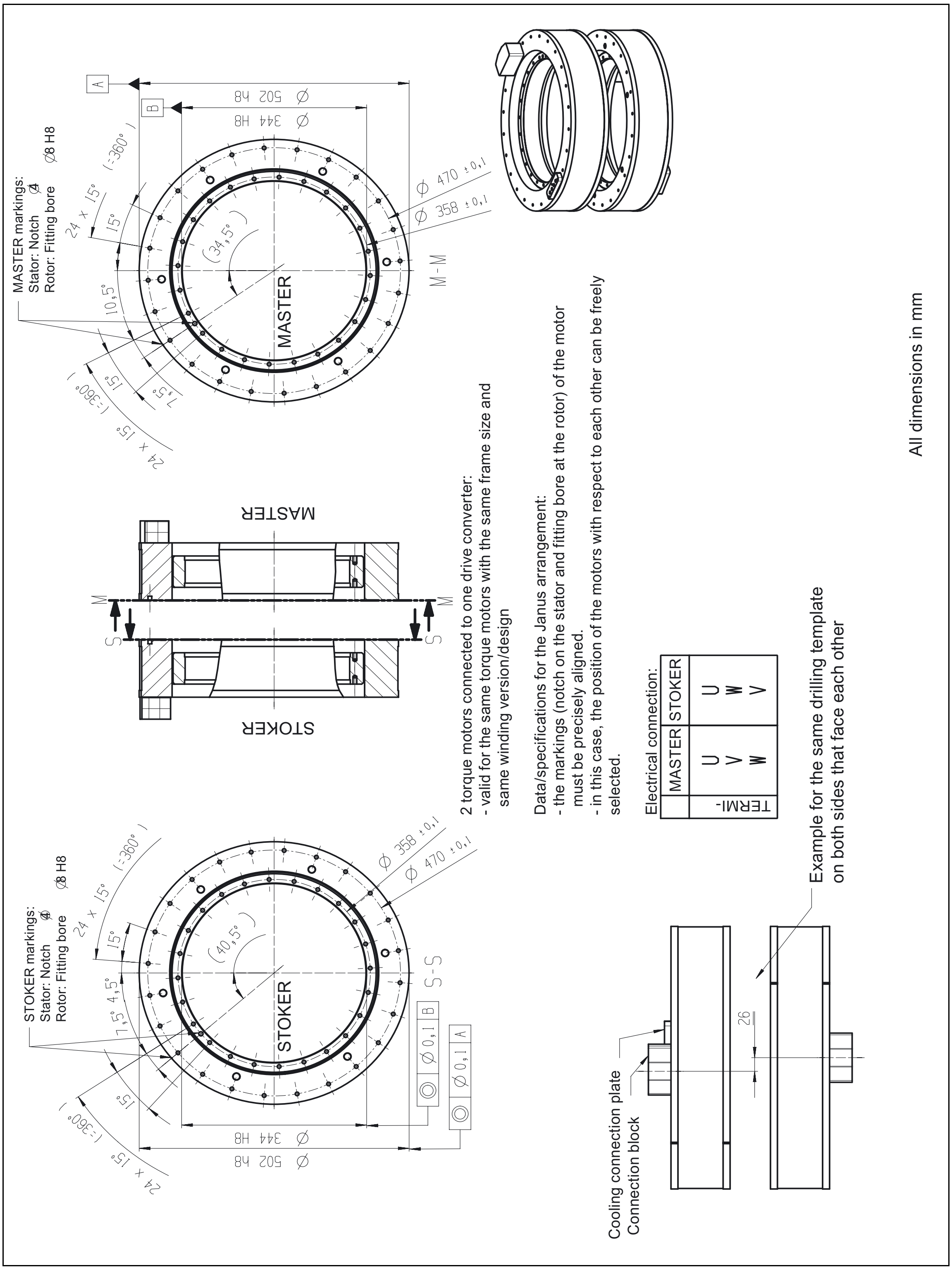


Figure 3-53: 1FW6190-0x... Janus arrangement

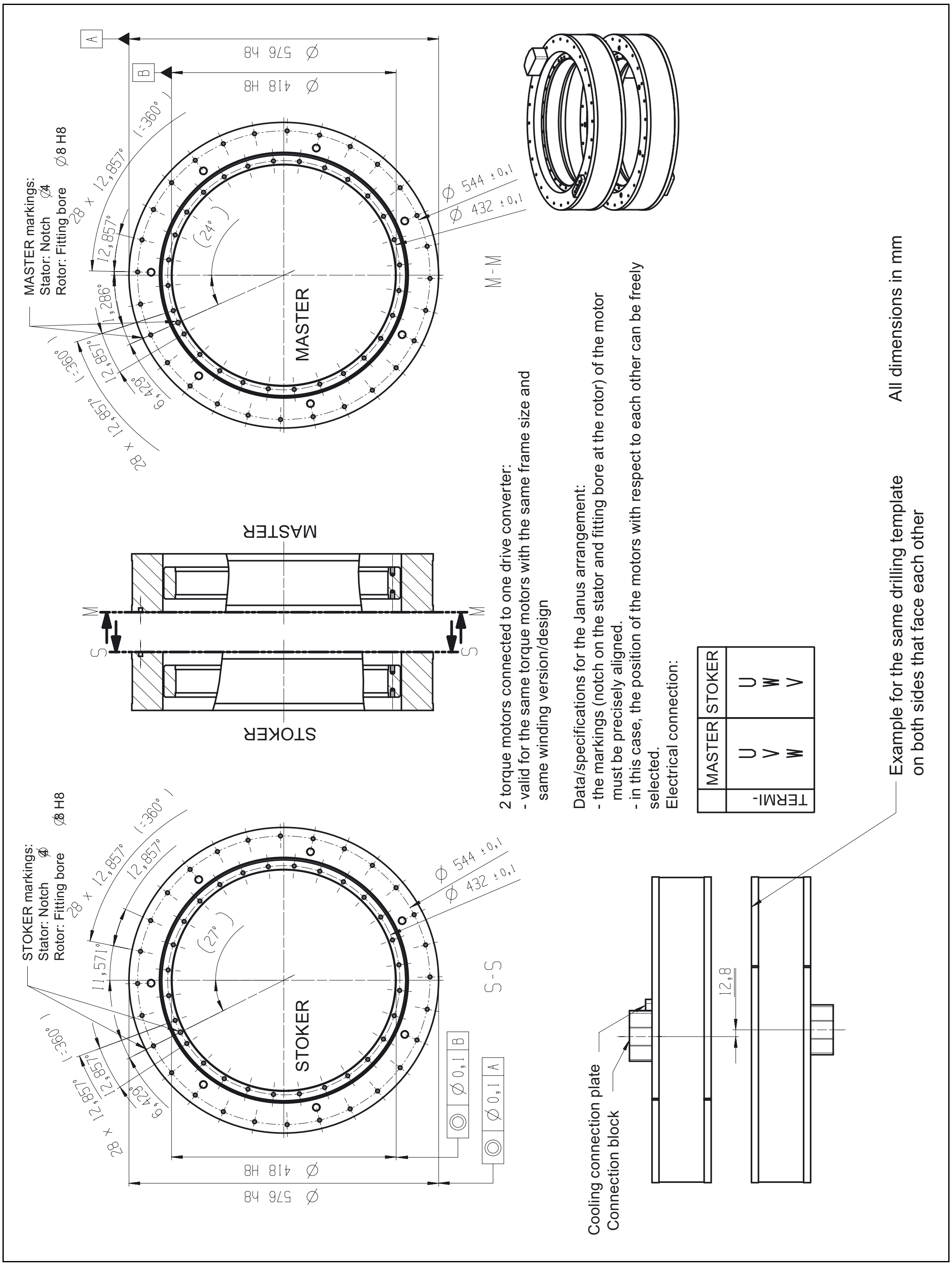


Figure 3-54: 1FW6230-0x... Janus arrangement

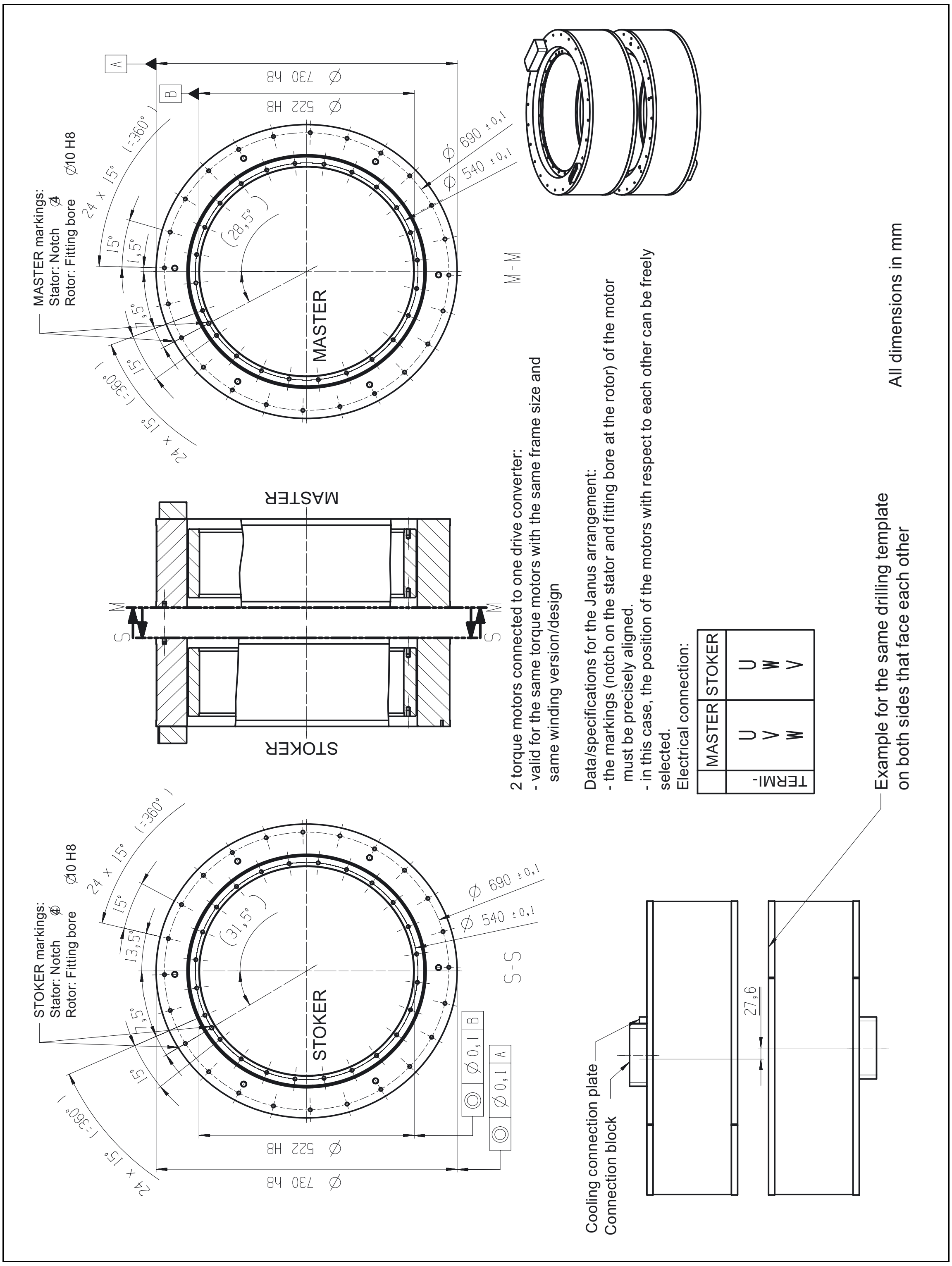


Figure 3-55: 1FW6290-0x... Janus arrangement

3.10 Using a holding brake

As a result of cogging torques, torque motors can be drawn into a magnetically preferred position if the motor is no longer being supplied from the drive converter. This means that if a motor is already stationary, it can unpredictably move by up to one half of a magnetic pole pitch in both directions. In order to avoid possible damage e.g. at the workpiece and/or at the tool, it may be practical to use a holding brake.

As a result of the fact that there is no self-locking/latching, for inclined or vertical drives without weight equalization, a holding brake should be provided in order to be able to stop the drive at any position and allow it to be brought into a no-voltage condition.

A holding brake can be required, if

- the bearing friction does not compensate or does not exceed the cogging torque and therefore result in unpredictable motion
- unpredictable drive motion can result in damage (e.g. if a motor with a high weight also reaches a high kinetic energy)
- drives with weight loads are stopped in any position and must be brought into a no-current condition

In order to avoid motion when powering-up and powering-down the drive, the holding brake reaction must be synchronized with the drive.

Carefully observe the documentation of the drive converter system being used when commissioning the system!

4 Motor Installation and Commissioning

4

4.1 Installing the motor

Before installing the motor you must carefully read the installation instructions provided in this Chapter.

4.1.1 Important information and instructions when installing the motor

Danger

Work must be carried-out in the immediate vicinity of unpacked rotors when the motors are being installed. This is the reason that dangers, caused by strong magnetic fields are especially high.

It is absolutely mandatory that you observe the information in the Chapter "Safety information and instructions" and the safety information and instructions provided in this Chapter.

Warning

The transport locks may only be removed just before the motor is installed in the machine.

The sequence (refer to Chapter "Procedure when installing the motor") must, under all conditions, be carefully observed!

Warning

The machine must be designed so that both the rotor as well as the stator are only retained at one side. Also refer to Chapter "Installation examples". - If retained at both ends, this can result in significant material stress levels in the machine assembly as a result of thermal expansion. This can destroy the motor.

Radial forces between the stator and rotor

Note

It is very important that you carefully observed the radial forces between the stator and rotor and the maximum permissible concentricity error specified in the dimension sheets.

Table 4-1: Radial forces in N/0.1 mm for radial centering errors during installation

	Active part length 50 mm	**Active part length 70 mm**	**Active part length 100 mm**	**Active part length 150 mm**
1FW6090	240	330	470	710
1FW6130-	360	500	710	1070
1FW6160-	290	410	590	880
1FW6190-	350	490	710	1060
1FW6230-	420	590	840	1260
1FW6290-	430	600	860	1280

Table 4-1 indicates the radial force in N per 0.1 mm centering error that is effective between the stator and rotor. The longer the active part, the greater this radial force.

Example:

For a torque motor 1FW6090-0Px010-xxxx the eccentricity is 0.5 mm.

The radial force that is then effective as a result of this centering error is

$$0{,}5\,\text{mm} \bullet \frac{470\,\text{N}}{0{,}1\,\text{mm}} = \underline{\underline{2350\,\text{N}}}$$

Axial forces between the stator and rotor

Table 4-2: Axial forces in N between the stator and rotor when assembled

	1FW6090	**1FW6130-**	**1FW6160-**	**1FW6190-**	**1FW6230-**	**1FW6290-**
Axial forces in N	80	120	210	250	300	450

Notice

The forces of attraction between the stator and rotor are up to 400 to 500% higher when the rotor is just about to be introduced into the stator.

Retaining system

The following information and instructions must be carefully observed when bolting the torque motor to the axis assembly:

- only use new (unused) retaining bolts
- observe the maximum permissible screw-in depth of the retaining bolts in the stator and rotor (refer to the relevant installation drawing)
- minimum screw-in depth of the retaining bolts in the aluminum flange of the stator: 1.3 x d (this is valid for 1FW6090 to 1FW6130);
  1.0 x d (this is valid from 1FW6160 due to the threaded insert)
- minimum screw-in depth of the retaining bolts in the flange of the rotor: 1.0 x d (in steel)
- the following effective length must be selected (clamping ratio): I_k / d > 5)
- Use bolts lubricated with MoS_2 (for the tightening torques recommended in Table 4-3)
- tighten the bolts using a calibrated torque wrench in pairs alternating diagonally

Explanation:
I_k = effective bolt length (clamping length) [mm]
d = nominal diameter of the bolt [mm] (e.g. M8 bolt: d = 8 mm)

Bolt material and tightening torques

Bolts with strength class 8.8 are required to retain the motor in the machine. The necessary tightening torques for the stator and rotor retaining bolts are listed in the following Table 4-3.

Table 4-3: Tightening torques required

Series	Stator		Rotor	
	Bolt (strength class)	Tightening torque M_A [Nm]	Bolt (strength class)	Tightening torque M_A [Nm]
1FW6090	M5 (8.8)	4.5	M5 (8.8)	4.5
1FW6130-xxx	M5 (8.8)	5.2	M5 (8.8)	5.2
1FW6160-xxx	M8 (8.8)	20	M8 (8.8)	20
1FW6190-xxx	M8 (8.8)	20	M8 (8.8)	20
1FW6230-xxx	M8 (8.8)	20	M8 (8.8)	20
1FW6290-xxx	M10 (8.8)	38	M10 (8.8)	38
Notes:	Frictional value used as basis µtotal = 0.1 (lubricated with MoS_2) The specified tightening torques are also valid when using bolts with a higher strength class			

4.1.2 Procedure when installing the motor

The procedure when installing 1FW6 built-in torque motors is sub-divided into the following steps:

1. Check and monitor the dimensions to accept the motor using the installation drawing
2. Clean the mounting surfaces of the motor components and the machine
3. Remove the transport locks on the side of the motor that will be retained. For 1FW6160 to 1FW6290 motors, additionally move the transport locks from the side of the motor that will be retained to the opposite side.
4. Install and retain the stator and rotor. Tighten the bolts with the specified torque.
5. Remove the transport locks on the opposite side.
   (Notice: Never remove beforehand!)
6. Remove the distance foil
7. Correctly connect-up or insulate the power connections (otherwise, when rotating there is a danger of induced voltage and ripple for a phase short-circuit)
8. Check that the rotor is free to move. Ensure that the distance foil and other foreign bodies are removed from the air gap.
9. Connect-up the cooling medium lines
10. Connect-up the power and signal cables

The individual working steps are described in detail in the following.

Warning

If the motor is installed in a different sequence this can represent danger to persons and/or destroy the motor components.

Check the installation dimensions to accept the motor

Check the dimensions to accept the motor using the installation drawings (refer to the Chapter "Dimension drawings / installation drawings").

Cleaning the mounting surfaces

- deburr and round-off the inner holes and bores (e.g. the cooling medium intake and outlet holes and bores) of the machine housing
- completely remove any machining remains such as chips, dirt and foreign bodies/particles
- grease or lubricate seals and components (check that the media being used are compatible to the elastomers)

Remove the transport locks on the retaining side

When originally shipped, the transport locks are mounted at the stator and rotor at both flange surfaces. Immediately before installing the motor, the transport locks are removed from the side of the motor that is to be bolted in place. For 1FW6160 to 1FW6290 motors, the transport locks from the side that is to be bolted are attached to the opposite side. The motor may only be carefully moved when the transport locks have been removed/released.

Motor installation and retaining

Fit the rotor and stator into the centering face provided and tighten the bolts with the specified torque. The transport locks on the opposite flange surface may only be released if the stator and rotor are centered with respect to one another in the machine and are secured against any magnetic forces that may occur. Special installation equipment is required if the stator and rotor are bolted to flange surfaces opposite to the machine.

a) Procedure for motors with a cooling jacket:

- locate both O-rings over the motor peripheral surface into the grooves provided
- with the flange surface at the front, introduce the motor into the bore of the machine housing. Ensure that the O-rings are neither dislocated from the groove nor damaged
- bolt the flange surface of the stator to the machine housing and the flange surface of the rotor to the moving axis (observe the tightening torques and sequence as specified in Chapter 4.1.1)

b) Procedure for motors with integrated cooling:

- with the transport locks removed from the flange surface, introduce the motor into the machine housing (observe the tightening torques and sequences as specified in Chapter 4.1.1)

Removing the transport locks at the opposite end

After the stator and rotor have been retained, the transport locks can be removed at the opposite flange end. Carefully store the transport locks as they maybe required for service & maintenance and when withdrawing the motor.

Cooler connection

Cooler connection for motors with integrated cooling

The cooler connections have a 1/8” pipe thread (DIN 2999). The appropriate connecting parts are required to connect the hoses (refer to the Chapter "Cooling connection system"). Generally, the connecting components can be installed using standard tools.

If the main and precision cooler are connected in parallel on a cooling unit, a cooling connection adapter can be purchased (Order No. refer to the Chapter "Motor rating plate and Order No."). The cooling connection adapter can either be axially or radially connected using a 1/4” pipe thread (DIN 2999).

Three cheese-head screws are used to mount the cooling connection adapter. The cooling ducts are sealed using O-rings (refer to Figure 4-1 ff). Cheese-head screws and O-rings are included with the cooling connection adapter.

Cooler connection for motors with cooling jacket

For motors with cooling jacket, the cooler is connected through the mechanical assembly. The cooling water line cross-sections depend on the cross-sections of the cooling grooves in the jacket. The grooves of the cooling jacket are sealed using the customer's housing (mechanical assembly) and the O-rings.

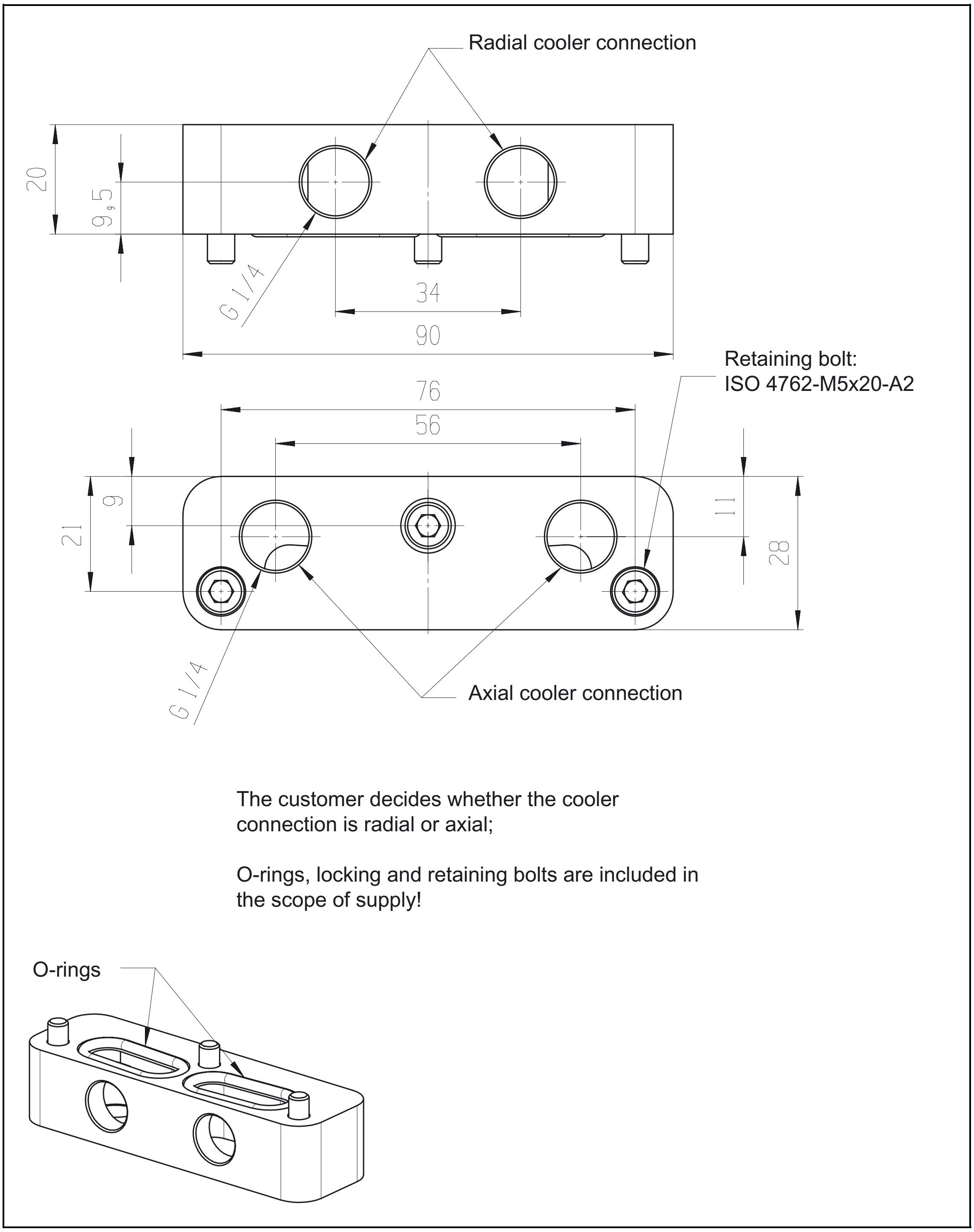


Figure 4-1: Cooling connection adapter 1FW6160, 1FW6190, 1FW6230

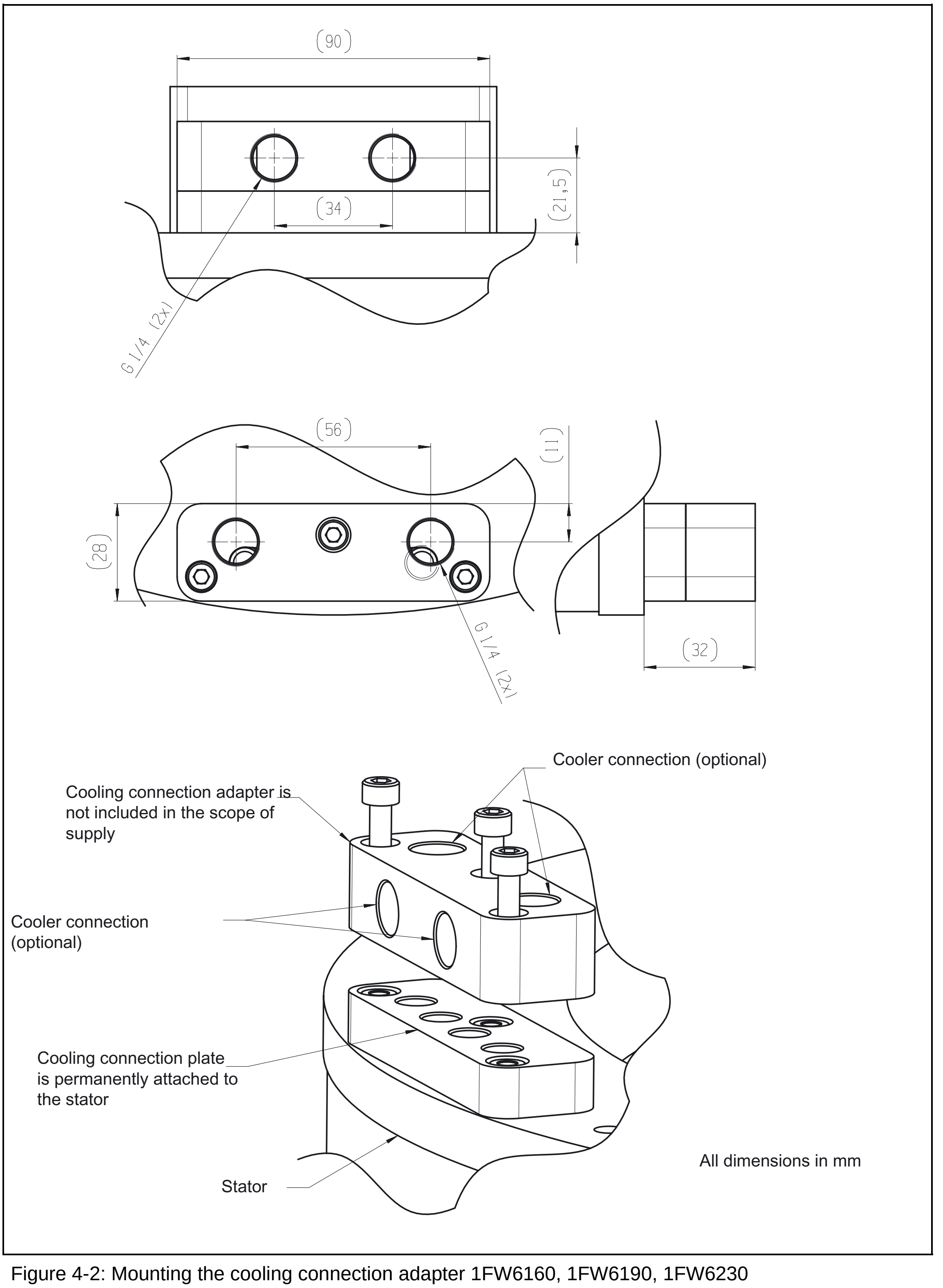


Figure 4-2: Mounting the cooling connection adapter 1FW6160, 1FW6190, 1FW6230

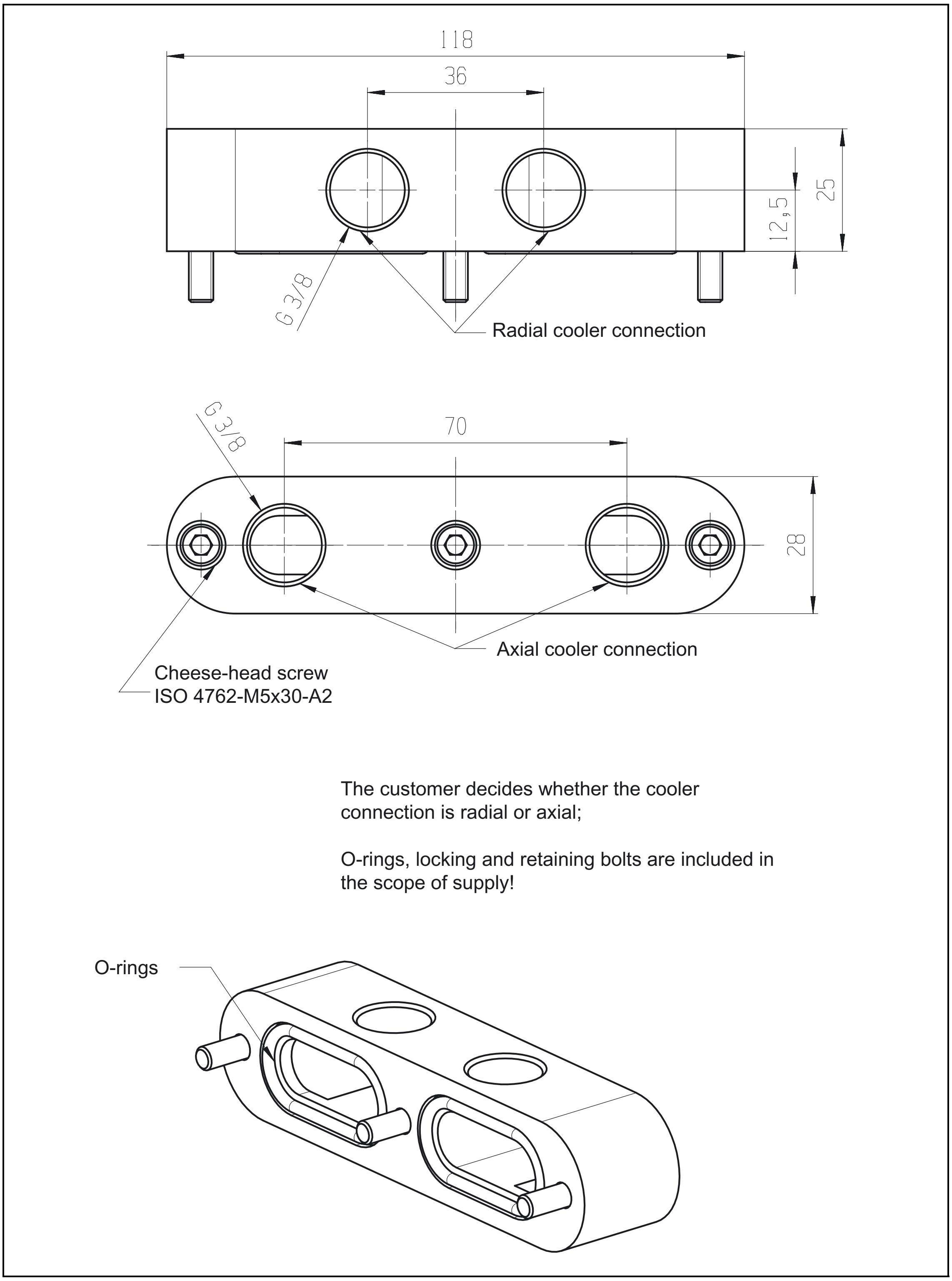


Figure 4-3: Cooling connection adapter 1FW6290

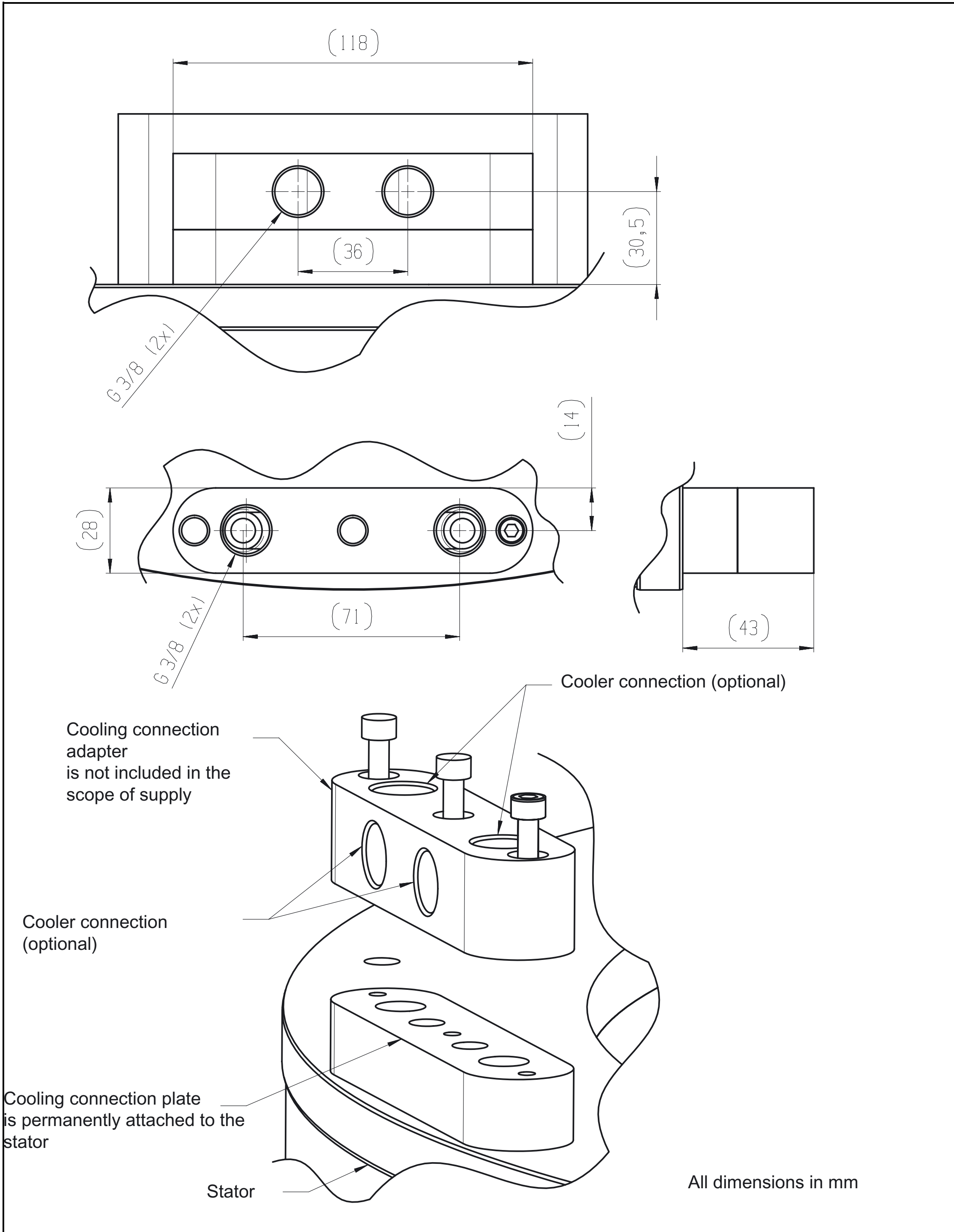


Figure 4-4: Mounting the cooling connection adapter 1FW6290

Information and instructions on routing cables

Please observe the following when routing and connecting-up the motor feeder cables :

- the minimum bending radii (refer to the Chapter "Electrical connection system" for power cables that can move must be complied with
(refer to Catalog NC 60).

- it is not permissible that the cables can rub against other parts and components

- the cables must be clamped at intervals of 200 mm or permanently retained

Requirements placed on the cables used

- sufficiently high dynamic load capability as a result of high rates of acceleration and velocities if the application demands it

Checking the work

After this work has been completed it must be carefully checked that the rotor is free to move. All tools and objects from the swiveling range and the air gap must be removed before rotating the rotor.

Danger

Danger due to electric shock!
Before the motor is rotated all of the power connections must be correctly connected or insulated!

- the assembled rotary axis must be able to freely rotate. Examples of axes that may not be able to be manually checked: large axes with the corresponding frictional torque, clamped in the no-current state, forces due to weight that are not equalized

Warning

Take extreme caution when releasing clamps/brakes in the uncontrolled state when powered-down. There is a potential hazard due to possible uncontrolled motion of the axis!

- All of the feeder cables must be routed and attached firmly in place so that they cannot be kinked, damaged or pressed against rotating parts and components

- Cooling medium lines must be free to move and the cooling medium must be able to flow without any restriction

4.2 Installation examples

Note

The following examples showing the principle neither claim to be complete nor do they claim to be generally applicable for every application.

Please note the single-sided retention - both the rotor as well as the stator are bolted to the machine assembly. Depending on the mechanical machine design, the stator can either be retained at the same end that the rotor is retained or at the opposite end.

Table 4-4: Information on the following examples showing principle installation types

Fig. No.	Fig. title	Explanation
Figure 4-5	Rotary table using a torque motor with integrated cooling	The mechanical design shown can be advantageous for precision applications and for swiveling tables subject to high machining forces. The angular encoder is integrated in the bearings.
Figure 4-6	Rotary table using a torque motor with cooling jacket	The mechanical design shown can be advantageous for precision applications, sub-units, applications requiring holding functionality and swiveling tables with integrated brake. It is compact and therefore very simple to integrate.
Figure 4-7	Swiveling drive using a torque motor with integrated cooling	The mechanical design shown can be advantageous for robots, automatic handling machines and tool changers. The angular encoder is well de-coupled from the heat source, i.e. the motor winding.
Figure 4-8	Steps when installing the torque motor at the shaft end of a swiveling drive	Left: When the motor is supplied the transport locks are attached to both flanges. Under no circumstances may they be simultaneously removed from both ends. Center: The transport locks are removed from the retaining side and the rotor is bolted with its flange to the shaft end. Right: The stator is positioned at the machine and is then bolted in place, manually tightening the bolts. Then, and only then are the transport locks and the distance foil (between the rotor and stator; state when shipped) removed. The stator retaining bolts are then tightened.
Figure 4-9	Swiveling drive using a torque motor with cooling jacket	The mechanical design shown can be advantageous for medium load forces and average precision requirements, e.g. in woodworking, for automatic packaging machines and for tool changers. For roller drives, this design is only suitable for short axes with low bend.
Figure 4-10	Roller drive with low shaft bend using a torque motor with integrated cooling	The mechanical design shown can be advantageous for roller drives requiring very low vibration (smooth running operation) and low positioning accuracy. In this case, a rotary encoder with an adequate angular resolution is suitable. The encoder should be mounted and mechanically connected so that it is de-coupled from the thermal expansion of the shaft.

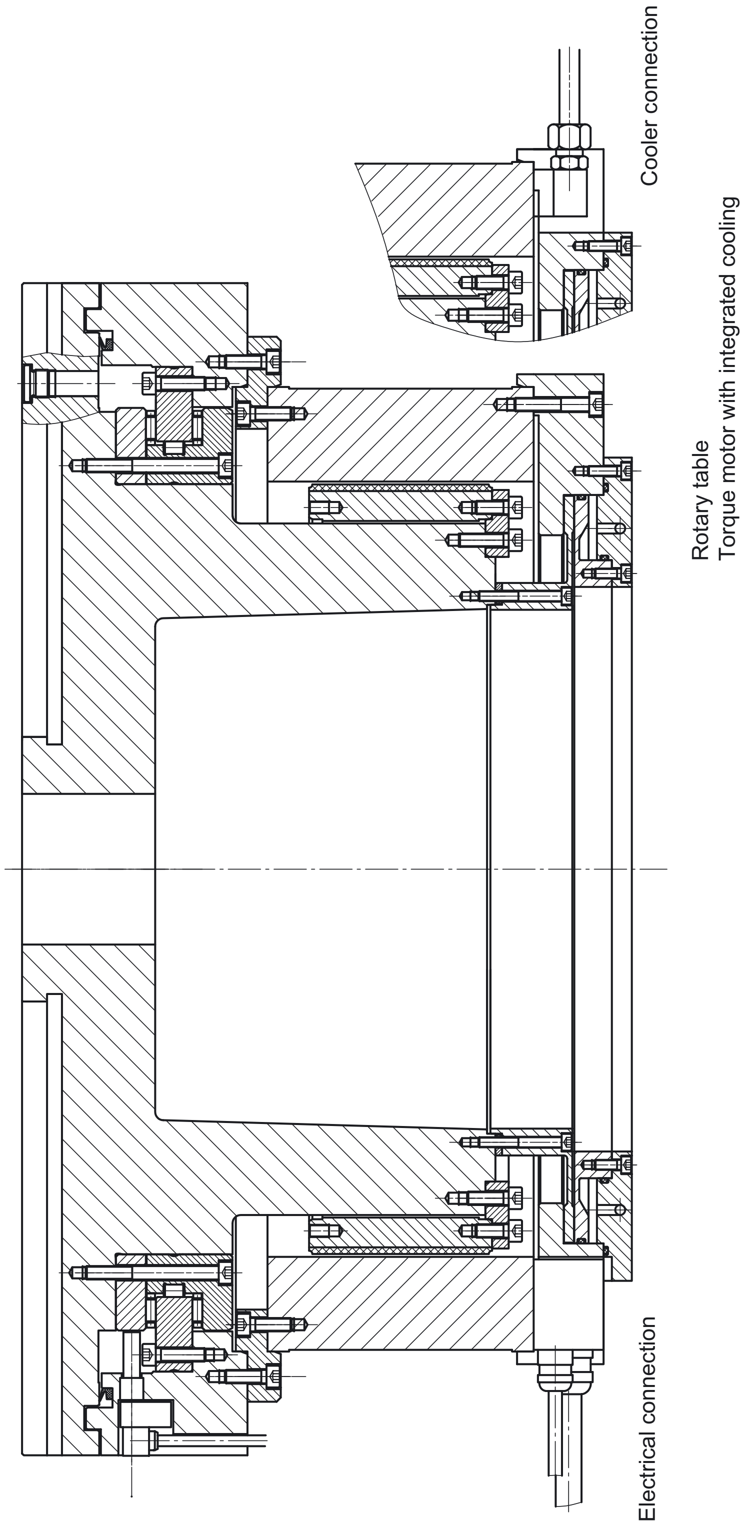


Figure 4-5: Rotary table using a torque motor with integrated cooling

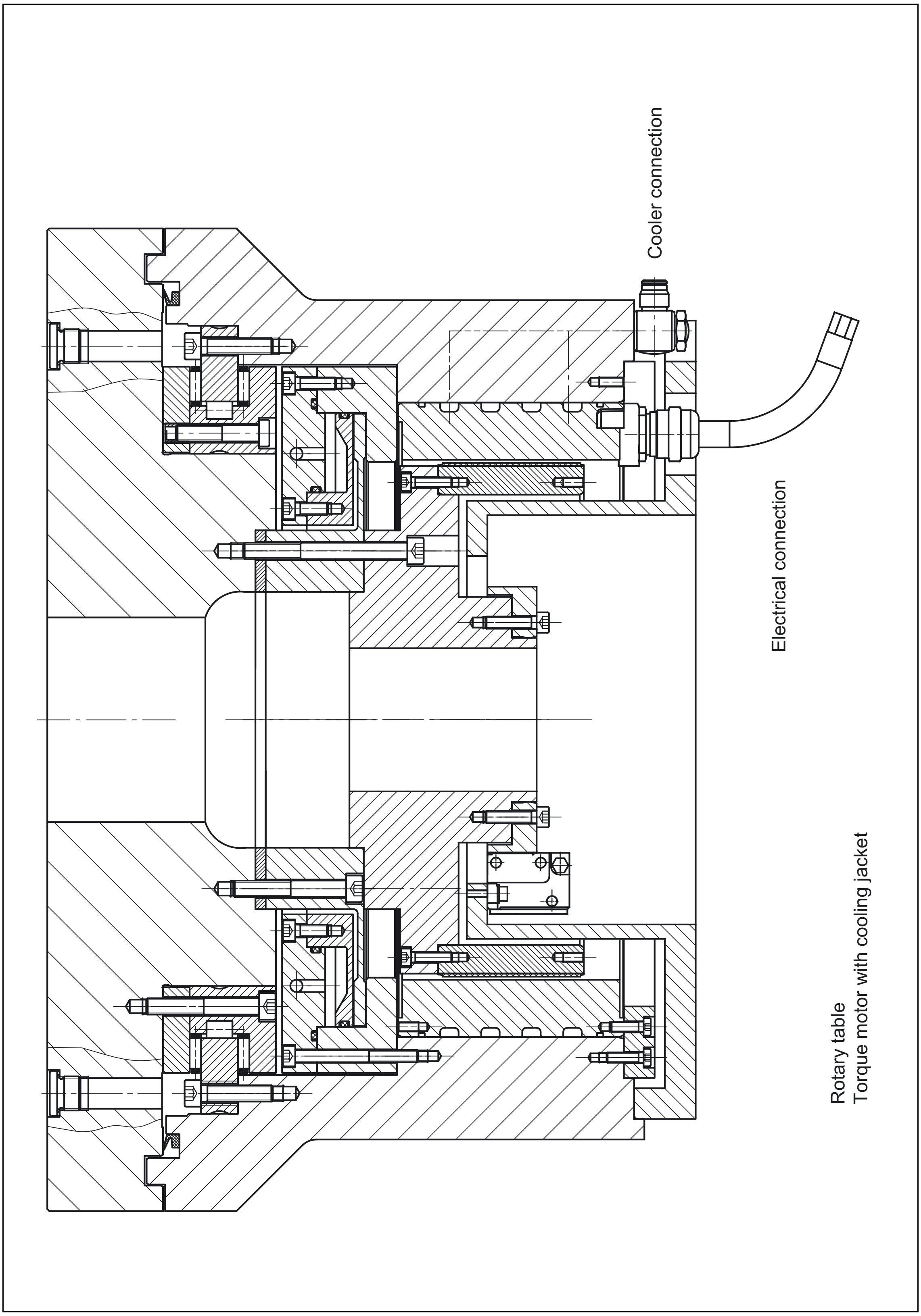


Figure 4-6: Rotary table using a torque motor with cooling jacket

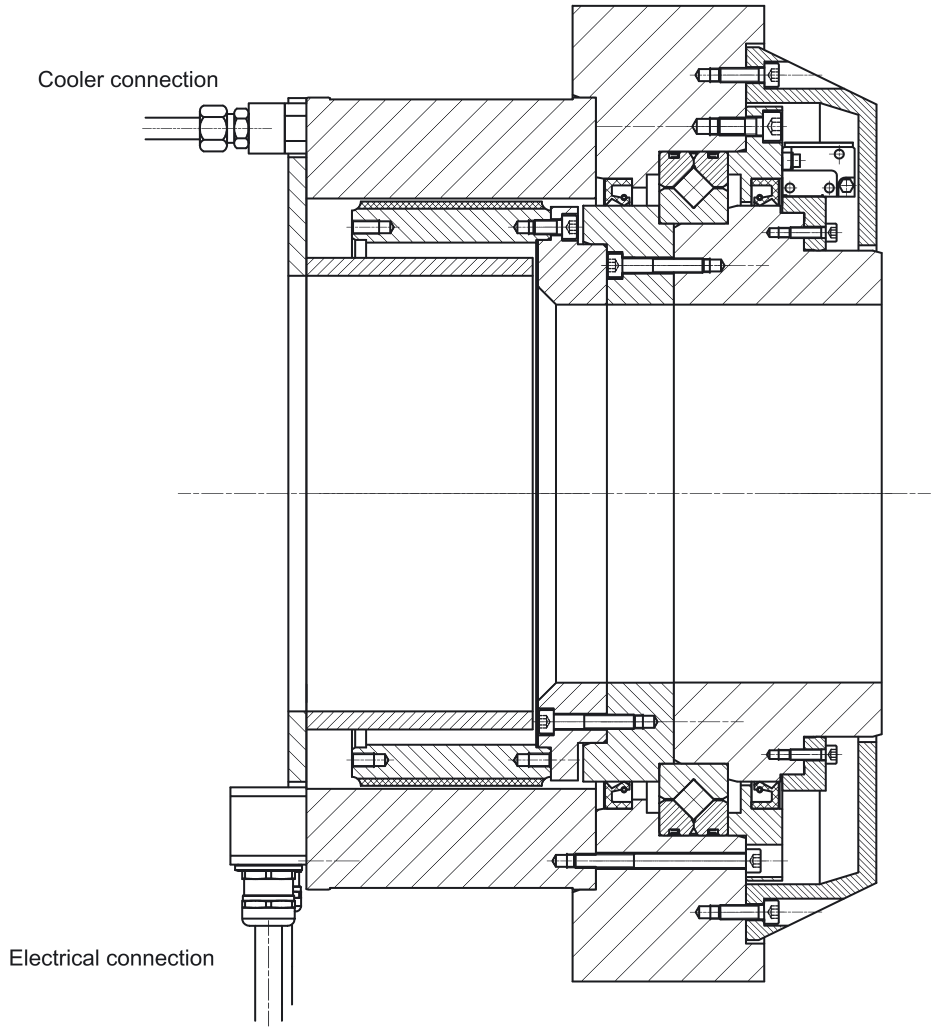


Figure 4-7: Swiveling drive using a torque motor with integrated cooling

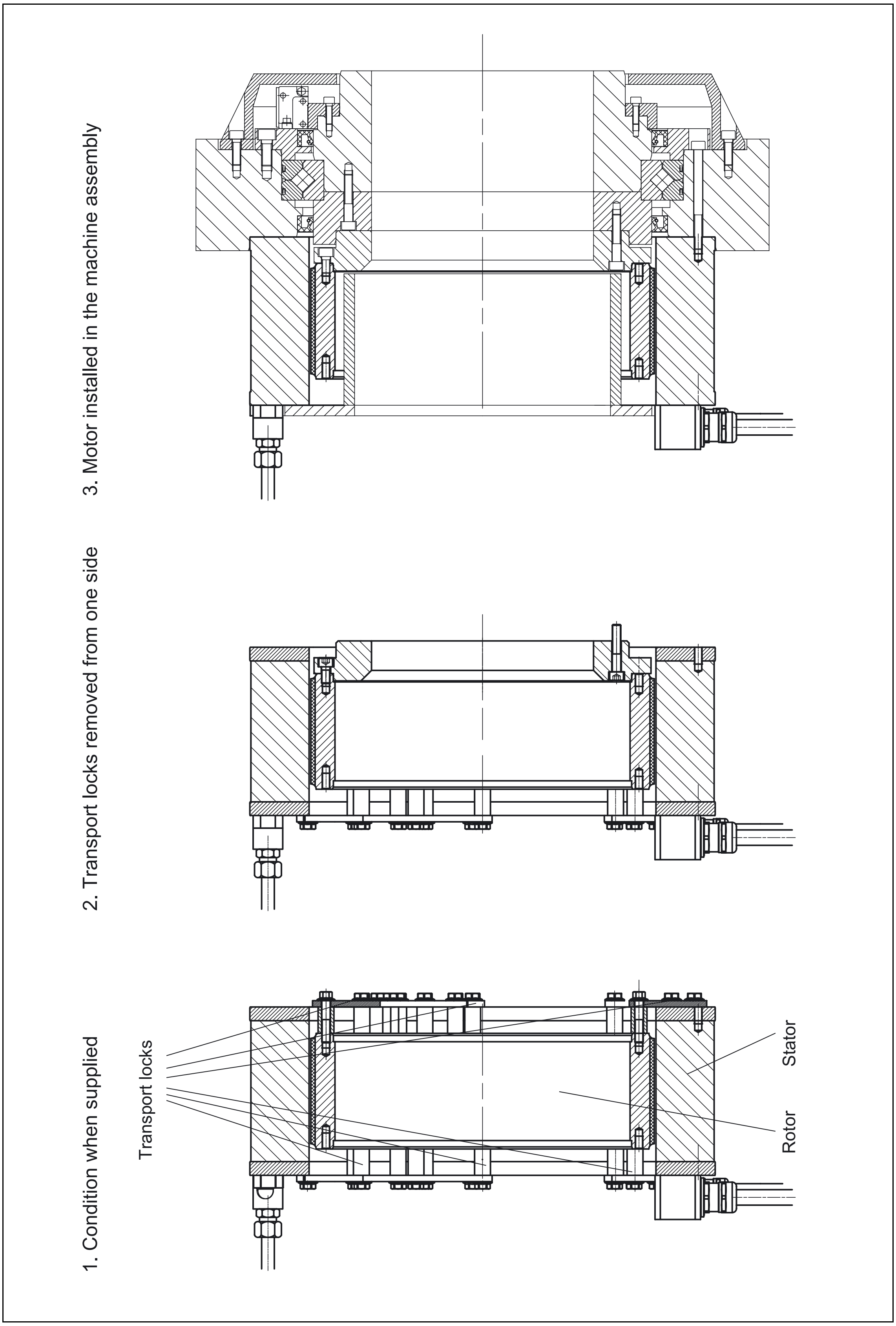


Figure 4-8: Steps when installing the torque motor at the shaft end of a swiveling drive

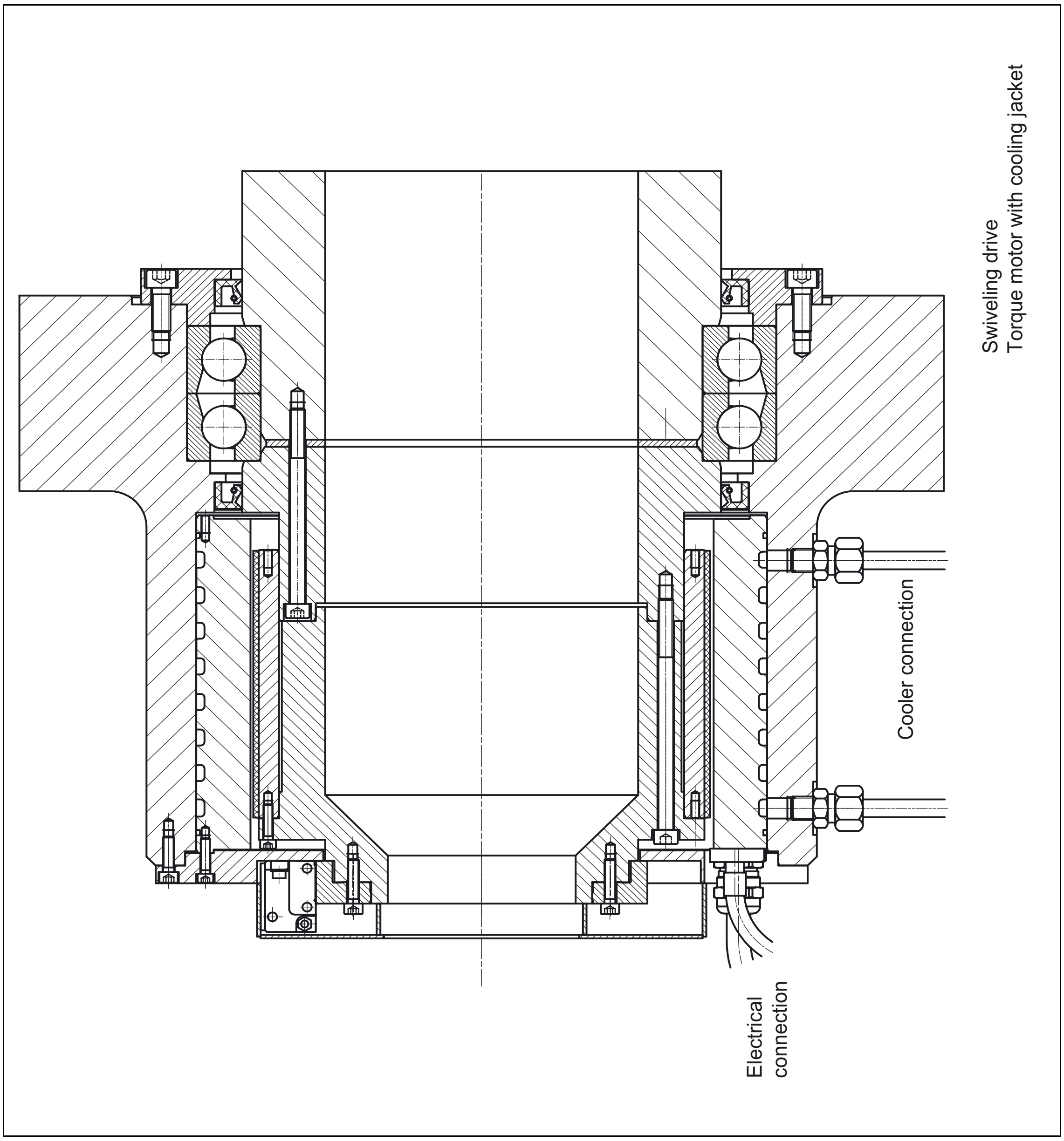


Figure 4-9: Swiveling drive using a torque motor with cooling jacket

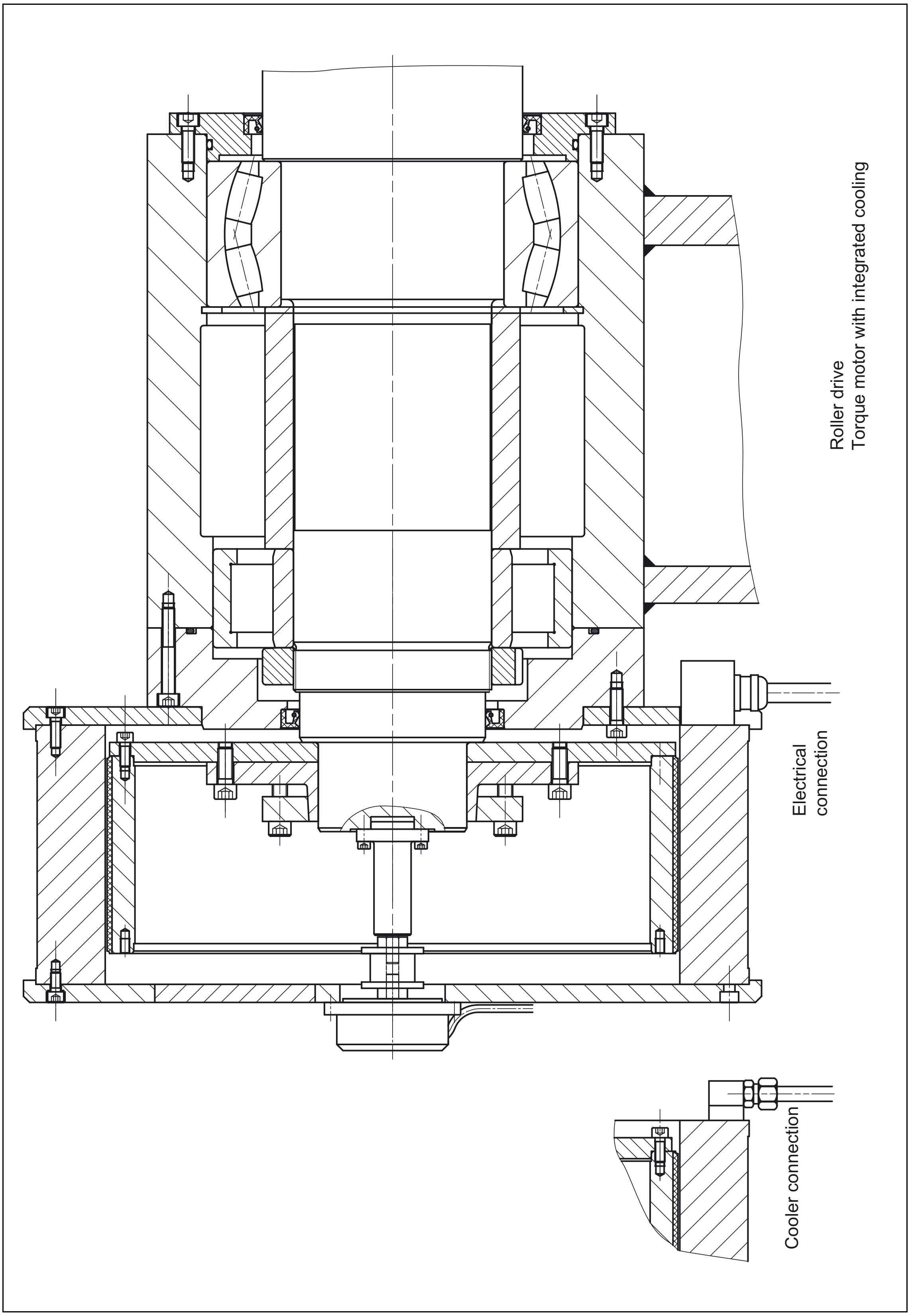


Figure 4-10: Roller drive with low shaft bend using a torque motor with integrated cooling

4.3 Protecting the motor components

Degree of protection

For built-in motors the required degree of protection is defined by the surrounding mechanical assembly. The better the **motor installation space** is protected against the ingress of foreign bodies (predominantly ferro-magnetic particles), the higher the lifetime.

This also applies to chemically aggressive substances (e.g. cooling-lubricating mediums, oils) that can enter the motor space. Chemically aggressive substances can have a negative impact on the adhesive that is used to attach the magnets to the rotor.

In operation, foreign objects in the air gap between the stator and rotor can mechanically destroy the motor.

Liquids that enter the motor can have a negative impact on the insulation strength of the stator.

The thermal motor characteristics are negatively influenced by liquids and foreign bodies that enter the motor.

The machine assembly that surrounds the motor must, as a minimum, have degree of protection IP54.

4.4 Commissioning

Danger

Avoid hazardous situations when commissioning torque motors.
Under all circumstances carefully observe the Chapter "Safety information and instructions" and the safety information and instructions in this Chapter.

For synchronous motors the encoder must be adjusted to the commutation angle. For 1FW6 torque motors this can be carried-out using the software-based automatic rotor position identification technique of the SIMODRIVE 611 digital/universal drive converter.

The following two techniques can be applied for all frame sizes of 1FW6 torque motors:

- the motion-based technique
- the induction-based technique

The measuring system must be very stiffly mounted if this technique is used.

It is no longer necessary to determine the angular commutation offset using an oscilloscope (also refer to "SINUMERIK 840 digital Commissioning Instructions").

Motion-based technique

The motion-based technique of the SIMODRIVE 611 digital drive converter can be used from software release (VSA) 05.03.24 for the Performance and High-Performance or High-Standard control boards (VSA-2) 06.03.xx and SIMODRIVE 611 universal drive converter from software release 6.1 and for the new control boards from VSA-2 06.xx.xx.

This technique can also be used during commissioning when determining the commutation angle for the first time or to check the angular commutation offset in conjunction with an absolute measuring system (e.g. RCN 727 from Heidenhain).

The technique can be used for vertical axes and for horizontal axes that do not sag (i.e. drop) when they are in the no-current condition. In this case, the axes must be free to move (i.e. not braked). (stiction < 10 % of the rated motor torque).

When this technique is applied, under worst case conditions, the rotor can move in the range of ± 5 Degrees.

Warning

When in the no-current condition, horizontal axes can sag (i.e. drop) if the center of gravity lies outside the axis of rotation. The angle of the axis cannot be checked all of the time.

Inductance-based technique

The inductance-based technique of the SIMODRIVE 611 digital drive converter can be used from software release (VSA) 05.01.10, of the SIMODRIVE 611 universal drive converter from software release 5.1 and for the control boards from VSA-2 06.xx.xx.

This technique does not cause the rotor to move which means that it can also be used for axes that are locked. However, axes that are not clamped can move. Depending on the actual mechanical design this technique can result in a higher noise level when the axis is powered-up during the identification routine.

Note

For precise operation, the inductance-based technique requires fine synchronization. This means that either a measuring system with a zero mark that can be evaluated or an absolute measuring system is required.

Under the following conditions, distance-coded measuring systems can be used as motor encoder for the closed-loop current and speed control for the SIMODRIVE 611 universal drive converter:

From software release 4.1 onwards, referencing is possible using distance-coded reference marks via PROFIBUS-DP in an external control. It is not possible to evaluate the coding in the board itself!

From software release 8.3 onwards, in the positioning mode, the SIMODRIVE 611 universal drive converter can independently reference without requiring an external control.

5 Technical Data 5

Technical data and characteristics of the 1FW6 built-in torque motors are specified in the Chapter. This collection of data provides motor data required when engineering drives and also includes additional data for more in-depth calculations as part of detailed investigations and problem analyses. We reserve the right to change this data.

Note

System-specific data refer to the combination of 1FW6 built-in torque motors with SIMODRIVE 611 digital/universal drive converter systems.

If not specified differently, this data applies for the following limitations/restrictions:

- the DC link voltage $V_{DC\ link}$ is 600 V, the drive converter output voltage V_{amax} is 425 V
- the motor is water cooled with a recommended minimum flow rate according to the data sheet and an intake temperature T_{INTAKE} of 35 °C
- the rated temperature of the motor winding T_N is 130 °C
- voltages and currents are specified as rms values

5.1 Explanation of the abbreviations used in the formulas

Limitations/secondary conditions

$V_{DC\ link}$

DC link voltage of the drive converter.
Note: For drive converter output voltages V_{amax}, refer to Chapter "System prerequisites".

T_{INTAKE}

Maximum water intake temperature for the water cooling of the main cooler and the precision cooler if the motor is to be utilized up to rated torque M_N. For changes to the rated torque for other T_{INTAKE}, refer to the characteristic in Chapter "Cooling".

T_N

Rated motor winding temperature.

Rated data

M_N

Rated motor torque.

I_N

Rated motor current at the rated torque M_N.

$n_{MAX,\ MN}$

Maximum speed up to which the drive can provide the rated torque M_N.

$P_{V,N}$

Rated motor power loss at the maximum permissible operating temperature of the motor winding.

Limiting data

M_{MAX}

Maximum motor torque.

I_{MAX}

Maximum motor current at the maximum torque M_{MAX}. Maximum possible load duration, refer to Chapter "Short-time duty S2".

$P_{EL,MAX}$

Electric power drawn by the motor at M_{MAX} and for a maximum permissible operating temperature of the motor winding.

Note

The sum of the output mechanical power P_{mech} and the power loss P_V results in the electric power drawn by the motor P_{EL}.
Also refer to the Chapter "Calculating the required infeed".

The rated electric power drawn by the motor at the rated operating point with $M = M_N$ and $n = n_{MAX,MN}$ can be calculated as follows:

$$P_{EL,N} = P_{mech,N} + P_{V,N} = 2p \bullet M_N \bullet n_{MAX,MN} + 3 \bullet R_{130} \bullet I_0^2$$

Friction and eddy current losses are taken into account by the fact that instead of I_N the higher current I_0 is used in the calculation.

$n_{MAX,mech}$

Maximum mechanical speed. This is obtained as a result of radial forces and mechanical limitations and constraints.

$n_{MAX, MMAX}$

Maximum speed up to which the drive can provide the maximum torque M_{MAX}.

$n_{MAX,0}$

No-load speed; maximum speed without a load.

M_0

Torque for speed n = rpm, where a uniform distribution of the load and power loss is guaranteed across all three motor phases.

I_0

Current (rms) of the motor at torque M_0 and speed n = rpm.

M_0^*

Thermal standstill torque if a uniform current does not flow through all of the three motor phases. The current distribution across the phases is not uniform in the following operating modes:

– standstill
– operation with short, cyclic rotary motion (< 1 pole pitch)
– for n << rpm

At the rated current the influence of saturation can be neglected which means the following approximately applies:

$M_0^* \approx 1 / \sqrt{2} \bullet M_0$

I_0^*

Thermal standstill current (rms) of the motor at M_0^*. The following applies:

$I_0^* \approx 1 / \sqrt{2} \bullet I_0$

Physical constants

$k_{T,20}$

Motor torque constant at a rotor temperature of 20 °C (this refers to the lower, linear range of the current-torque characteristic).

k_E

Voltage constant to calculate the counter-induced, phase-to-phase voltage.

$k_{M,20}$

Motor constant for a winding temperature of T = 20 °C

The motor constant $k_M(T)$ can be calculated for other temperatures:
$k_M(T) = k_M,20 \bullet [1 + a(T – 20°C)]$

with the temperature coefficients a = - 0.001 1/K for magnets

$k_M(T) = k_{M,20} \bullet [1 - 0.001 \bullet (T – 20°C)]$

t_{TH}

Thermal time constant of the winding. This is obtained from the temperature characteristic of the winding when subject to a sudden load (step function) with a constant current, refer to the following diagram. After time t_{TH} has expired, the motor winding reaches approximately 63 % of its final end temperature T_{LIMIT} if the temperature protection function does not become effective beforehand.

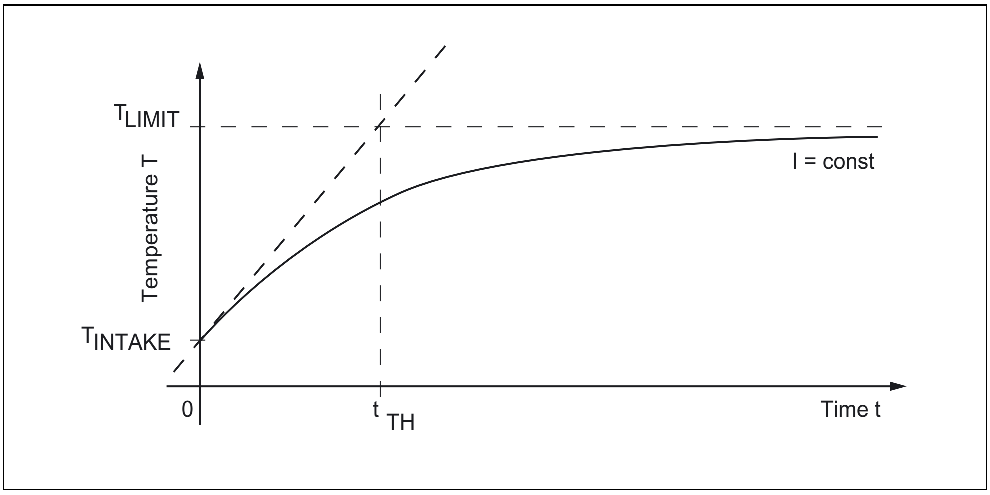


Figure 5-1: Thermal time constant

p

Pole pair number of the motor.

M_{COG}

Cogging torque. This is the torque as a result of the alternating effect between the laminated core and the permanent magnets at the air gap when the stator is in a no-current condition.

m_s

Weight of the stator without retaining bolts, connectors, connecting cables and cooling medium.

m_L

Weight of the rotor without retaining bolts.

J_L

Rotor moment of inertia.

$R_{PH,20}$

Phase resistance of the winding for a winding temperature of 20°C.

The value of the phase resistance is required, among other things to calculate the power loss. R_{20} can be converted to other phase resistances as follows:

$R_{PH}(T) = R_{PH,20} \bullet [1 + \alpha (T - 20°C)]$

with the temperature coefficients $\alpha = 0.00393 \bullet 1/K$ for copper

The following applies for $R_{PH,130}$: $R_{PH,130} = R_{PH,20} \bullet 1.4323$

L_{PH}

Phase inductance of the stator winding with the rotor installed.

Data, main motor cooler

$Q_{H,MAX}$

Maximum thermal power dissipated by the main cooler when the motor is utilized up to the rated torque M_N and at the maximum permissible operating temperature of the motor winding.

$\dot{V}_{H,MIN}$

Recommended minimum flow rate in the main cooler to reach the rated torque M_N.

ΔT_H

Temperature rise of the cooling medium between the intake and outlet of the main cooler at operating point $Q_{H,MAX}$ and $\dot{V}_{H,MIN}$.

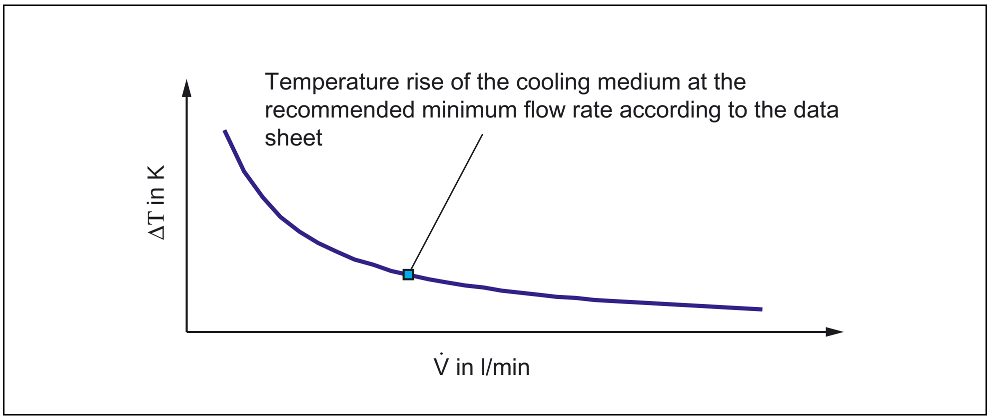


Figure 5-2: Example of a characteristic "Temperature rise of the cooling medium between the intake and outlet of the main cooler"

Δp_H

Pressure drop of the cooling medium between the intake and return line of the main cooler for flow rate $\dot{V}_{H,MIN}$.

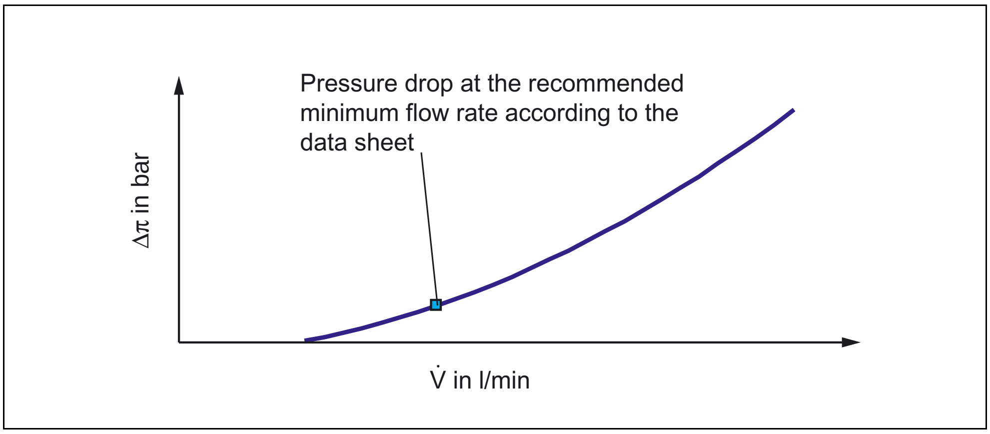


Figure 5-3: Example of a characteristic "Pressure losses of the main cooler as a function of the flow rate"

Data, motor precision cooler

$Q_{P,MAX}$

Maximum thermal power dissipated by the precision cooler when the motor is utilized up to its rated torque M_N and for the maximum permissible operating temperature of the motor winding.

$\dot{V}_{P, MIN}$

Recommended minimum flow rate in the precision cooler to achieve a minimum temperature increase at the mounting surface of the stator with respect to T_{INTAKE}.

ΔT_P

Temperature rise of the cooling medium between the intake and outlet in the precision cooler for the flow rate $\dot{V}_{P, MIN}$.

Δp_P

Pressure drop of the cooling medium between the intake and outlet in the precision cooler for a flow rate $\dot{V}_{P, MIN}$.

Speed-torque diagram

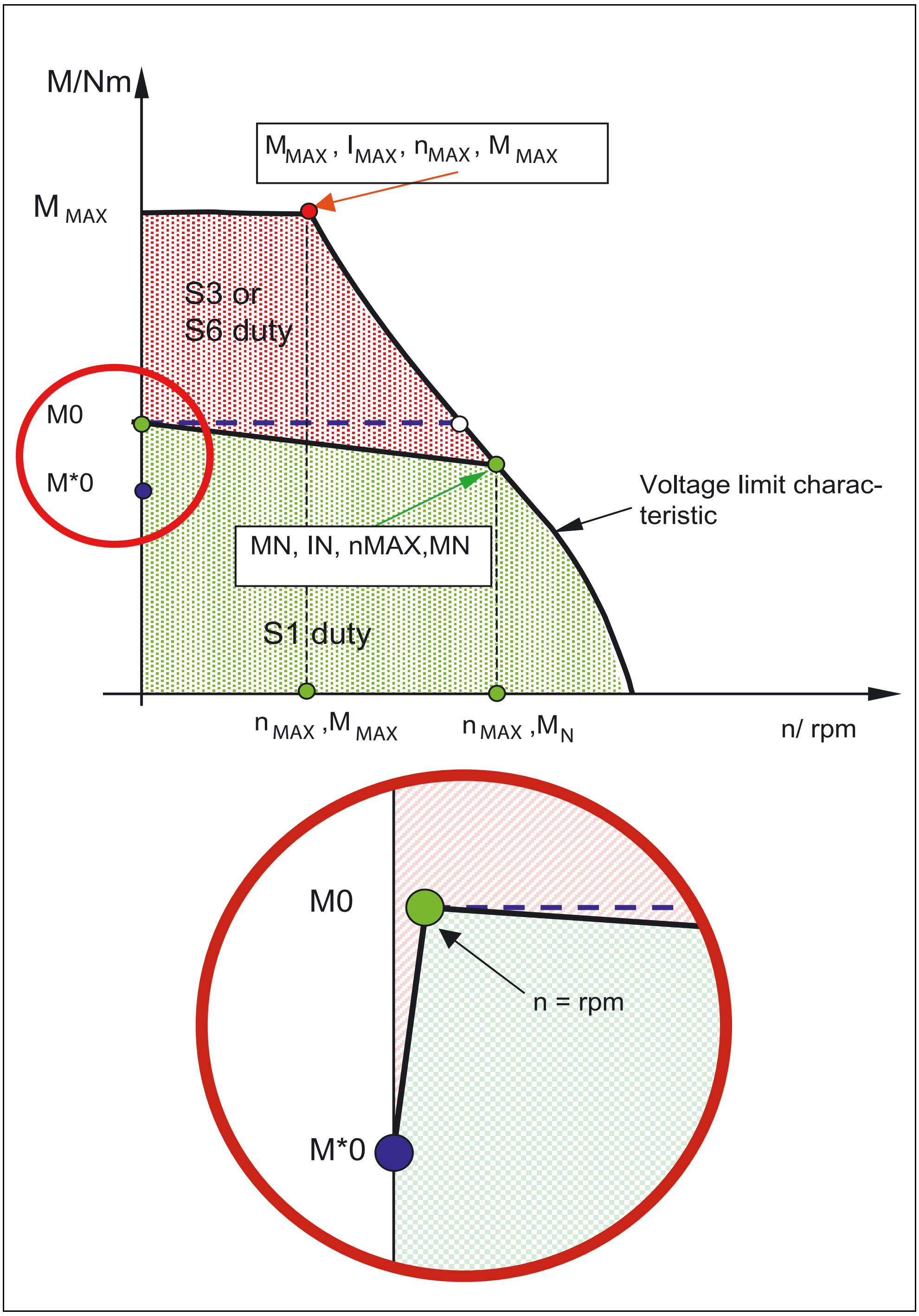


Figure 5-4: Description of a speed-torque diagram (example)

The speed-torque diagrams for the motor are provided in Chapter "Technical data and characteristics".

The circle located along the torque axis represents M^*_0.

The motors described have a high number of poles and have an adequately high thermal time constant. This means that even at extremely low speeds torque M_0 can be reached.

5.2 Overview of built-in torque motors

Table 5-1: Overview of motor data for 1FW6 built-in torque motors

Order No. [Frame size]	Rated torque (1) [Nm]	Maximum torque [Nm]	Rated current (1) [A]	Maximum current [A]	Max. speed at rated torque (2) [rpm]	Max. speed at maximum torque (2) [rpm]
1FW6090-xxx05-0Fxx	113	179	5.6	9.5	140	46
1FW6090-xxx05-0Kxx	109	179	7.4	13	250	140
1FW6090-xxx07-0Kxx	154	251	9.5	16	220	120
1FW6090-xxx07-1Jxx	142	251	13	26	430	270
1FW6090-xxx10-0Kxx	231	358	7.9	13	82	8.7
1FW6090-xxx10-1Jxx	216	358	14	26	270	170
1FW6090-xxx15-1Jxx	338	537	15	26	150	78
1FW6090-xxx15-2Jxx	319	537	23	43	310	200
1FW6130-xxx05-0Kxx	241	439	9	18	130	47
1FW6130-xxx05-1Jxx	217	439	14	32	310	180
1FW6130-xxx07-0Kxx	344	614	10	20	96	21
1FW6130-xxx07-1Jxx	324	614	15	32	200	110
1FW6130-xxx10-1Jxx	484	878	16	32	120	50
1FW6130-xxx10-2Jxx	450	878	24	53	250	150
1FW6130-xxx15-1Jxx	744	1320	18	36	78	14
1FW6130-xxx15-2Jxx	714	1320	26	54	150	77
1FW6160-xxx05-1Jxx	431	716	16	31	140	84
1FW6160-xxx05-2Jxx	404	716	24	49	250	150
1FW6160-xxx07-1Jxx	620	1000	16	31	96	53
1FW6160-xxx07-2Jxx	594	1000	25	49	170	100
1FW6160-xxx10-1Jxx	903	1430	17	31	60	29
1FW6160-xxx10-2Jxx	878	1430	26	49	110	65
1FW6160-xxx15-2Jxx	1350	2150	26	49	66	34
1FW6160-xxx15-5Gxx	1280	2150	50	98	160	97

Order No. [Frame size]	Rated torque (1) [Nm]	Maximum torque [Nm]	Rated current (1) [A]	Maximum current [A]	Max. speed at rated torque (2) [rpm]	Max. speed at maximum torque (2) [rpm]
1FW6190-xxx05-1Jxx	633	990	17	31	97	54
1FW6190-xxx05-2Jxx	605	990	24	47	160	96
1FW6190-xxx07-1Jxx	905	1390	17	31	63	33
1FW6190-xxx07-2Jxx	879	1390	25	47	110	64
1FW6190-xxx10-1Jxx	1310	1980	17	31	38	14
1FW6190-xxx10-2Jxx	1290	1980	26	47	70	39
1FW6190-xxx15-2Jxx	1970	2970	26	47	40	17
1FW6190-xxx15-5Gxx	1890	2970	50	95	100	62
1FW6230-xxx05-1Jxx	799	1320	15	31	69	34
1FW6230-xxx05-2Jxx	774	1320	22	45	110	59
1FW6230-xxx07-1Jxx	1140	1840	16	31	45	19
1FW6230-xxx07-2Jxx	1120	1840	22	45	73	38
1FW6230-xxx10-2Jxx	1630	2630	23	45	46	21
1FW6230-xxx10-5Gxx	1520	2630	48	100	130	74
1FW6230-xxx15-4Cxx	2440	3950	32	63	43	19
1FW6230-xxx15-5Gxx	2380	3950	49	100	80	44
1FW6290-xxx15-7Axx	4590	8570	61	130	53	28

(1) For water cooling [35° C]

(2) Speed and current values refer to a drive converter DC link voltage of 600 V

Order No. [Frame size]	Rated power loss (1) [W]	Outer diameter, stator [mm]	Inner diameter, rotor [mm]	Stator length [mm]	Motor weight (3) [kg]	Rotor moment of inertia [10^{-2} kg m^2]
1FW6090-xxx05-0Fxx	2190	230	140	90	9.2	1.52
1FW6090-xxx05-0Kxx	2120	230	140	90	9.2	1.52
1FW6090-xxx07-0Kxx	2690	230	140	110	12.2	2.2
1FW6090-xxx07-1Jxx	2670	230	140	110	12.2	2.2
1FW6090-xxx10-0Kxx	3500	230	140	140	17.2	3.09
1FW6090-xxx10-1Jxx	3500	230	140	140	17.2	3.09
1FW6090-xxx15-1Jxx	4870	230	140	190	27.2	4.65
1FW6090-xxx15-2Jxx	4960	230	140	190	27.2	4.65
1FW6130-xxx05-0Kxx	2930	310	220	90	13.2	6.37
1FW6130-xxx05-1Jxx	2930	310	220	90	13.2	6.37
1FW6130-xxx07-0Kxx	3730	310	220	110	18.2	8.92
1FW6130-xxx07-1Jxx	3710	310	220	110	18.2	8.92
1FW6130-xxx10-1Jxx	4880	310	220	140	25.2	12.7
1FW6130-xxx10-2Jxx	4980	310	220	140	25.2	12.7
1FW6130-xxx15-1Jxx	6810	310	220	190	38.2	19.1
1FW6130-xxx15-2Jxx	6810	310	220	190	38.2	19.1
1FW6160-xxx05-1Jxx	2840	440	280	110	36.3	19
1FW6160-xxx05-2Jxx	2850	440	280	110	36.3	19
1FW6160-xxx07-1Jxx	3590	440	280	130	48.3	25.8
1FW6160-xxx07-2Jxx	3610	440	280	130	48.3	25.8
1FW6160-xxx10-1Jxx	4720	440	280	160	66.3	36
1FW6160-xxx10-2Jxx	4740	440	280	160	66.3	36
1FW6160-xxx15-2Jxx	6620	440	280	210	95.3	53.1
1FW6160-xxx15-5Gxx	6670	440	280	210	95.3	53.1

Order No. [Frame size]	Rated power loss (1) [W]	Outer diameter, stator [mm]	Inner diameter, rotor [mm]	Stator length [mm]	Motor weight (3) [kg]	Rotor moment of inertia [10^{-2kg} m^2]
1FW6190-xxx05-1Jxx	3510	502	342	110	42.8	35.8
1FW6190-xxx05-2Jxx	3510	502	342	110	42.8	35.8
1FW6190-xxx07-1Jxx	4440	502	342	130	55.8	48.6
1FW6190-xxx07-2Jxx	4440	502	342	130	55.8	48.6
1FW6190-xxx10-1Jxx	5830	502	342	160	75.8	67.8
1FW6190-xxx10-2Jxx	5830	502	342	160	75.8	67.8
1FW6190-xxx15-2Jxx	8140	502	342	210	107.8	99.8
1FW6190-xxx15-5Gxx	8140	502	342	210	107.8	99.8
1FW6230-xxx05-1Jxx	3540	576	416	110	44.8	62.2
1FW6230-xxx05-2Jxx	3650	576	416	110	44.8	62.2
1FW6230-xxx07-1Jxx	4470	576	416	130	58.8	84.3
1FW6230-xxx07-2Jxx	4610	576	416	130	58.8	84.3
1FW6230-xxx10-2Jxx	6050	576	416	160	81.8	118
1FW6230-xxx10-5Gxx	6090	576	416	160	81.8	118
1FW6230-xxx15-4Cxx	8510	576	416	210	117.8	173
1FW6230-xxx15-5Gxx	8290	576	416	210	117.8	173
1FW6290-xxx15-7Axx	9080	730	520	220	214.6	440

(1) For water cooling [35° C]

(3) Motor weight without the weight of the transport locks

5.3 Technical data and characteristics

5.3.1 1FW6090-xxxxx-xxxx

Table 5-2: 1FW6090-xxx05-0Fxx, 1FW6090-xxx05-0Kxx

1FW6090					
Technical Data	**Code**	**Units**	**-xxx05-0Fxx**	**-xxx05-0Kxx**	
Limitations					
DC link voltage	$V_{DC\ link}$	V	600	600	
Intake temperature of the water cooling	T_{INTAKE}	°C	35	35	
Rated temperature of the winding	T_N	°C	130	130	
Data at the rated operating point					
Rated torque	M_N	Nm	113	109	
Rated current	I_N	A	5.6	7.4	
Maximum speed at the rated torque	$n_{MAX,MN}$	rpm	140	250	
Rated power loss	$P_{V,N}$	W	2190	2120	
Limiting data					
Maximum torque	M_{MAX}	Nm	179	179	
Maximum current	I_{MAX}	A	9.5	13	
Electric power of the motor at M_{MAX}	$P_{EL,MAX}$	W	6550	8120	
Maximum mechanical speed	$n_{MAX,mech}$	rpm	1100	1100	
Maximum speed at the maximum torque	$n_{MAX,MMAX}$	rpm	46	140	
No-load speed	$n_{MAX,0}$	rpm	310	430	
Torque at n = rpm	M_0	Nm	119	119	
Current at M_0 and n = rpm	I_0	A	5.9	8.2	
Thermal standstill torque	M_0^*	Nm	84.1	84.1	
Thermal standstill current	I_0^*	A	4.1	5.6	
Physical constants					
Torque constant at 20 °C	$k_{T,20}$	Nm/A	20.8	15	
Voltage constant	kE	V/(1000/min)	1258	906.2	
Motor constant at 20 °C	$k_{M,20}$	$Nm/\sqrt{W}$	2.64	2.68	
Thermal time constant	t_{TH}	s	60	60	
Pole pair No.	p	-	22	22	
Cogging torque	M_{COG}	Nm	1.2	1.2	
Stator weight	m_S	kg	6.6	6.6	
Rotor weight	m_L	kg	2.6	2.6	
Rotor moment of inertia	J_L	10^{-2} kgm^2	1.52	1.52	
Winding phase resistance at 20 °C	$R_{PH,20}$	Ω	14.9	7.5	
Winding phase inductance	L_{PH}	mH	47.1	24.4	
Data, main motor cooler					
Maximum dissipated thermal power	$Q_{H,MAX}$	W	2190	2120	
Recommended minimum flow rate	$\dot{V}_{H,MIN}$	l/min	3.4	3.4	
Temperature rise of the cooling medium	DT_H	K	9.2	9	
Pressure drop	Dp_H	bar	0.1	0.1	

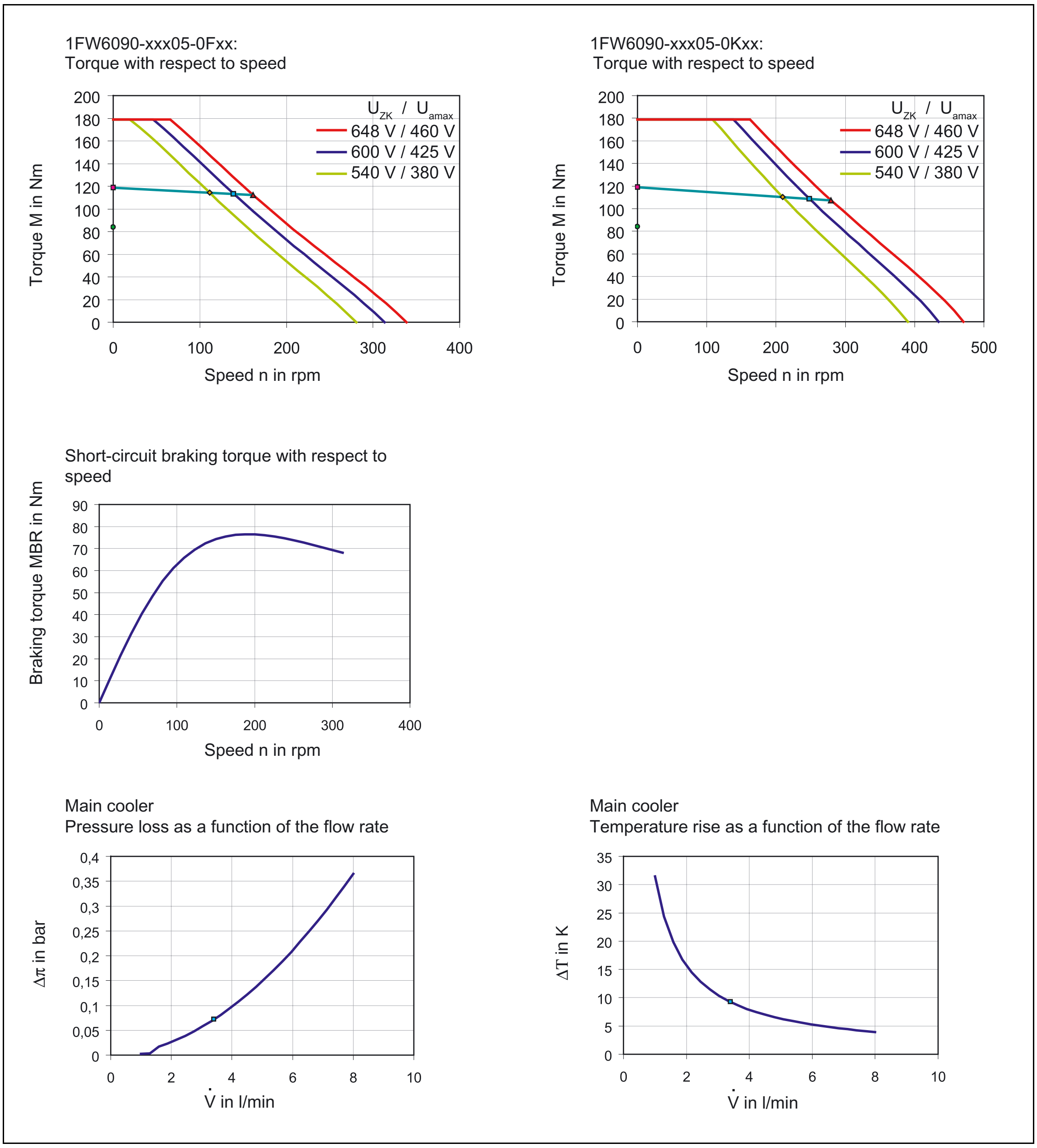


Figure 5-5: Characteristics for 1FW6090-xxx05-0Fxx, 1FW6090-xxx05-0Kxx

Table 5-3: 1FW6090-xxx07-0Kxx, 1FW6090-xxx07-1Jxx

1FW6090					
Technical Data	**Code**	**Units**	**-xxx07-0Kxx**	**-xxx07-1Jxx**	
Limitations					
DC link voltage	$V_{DC\ link}$	V	600	600	
Intake temperature of the water cooling	T_{INTAKE}	°C	35	35	
Rated temperature of the winding	T_N	°C	130	130	
Data at the rated operating point					
Rated torque	M_N	Nm	154	142	
Rated current	I_N	A	9.5	13	
Maximum speed at the rated torque	$n_{MAX,MN}$	rpm	220	430	
Rated power loss	$P_{V,N}$	W	2690	2670	
Limiting data					
Maximum torque	M_{MAX}	Nm	251	251	
Maximum current	I_{MAX}	A	16	26	
Electric power of the motor at M_{MAX}	$P_{EL,MAX}$	W	10300	14100	
Maximum mechanical speed	$n_{MAX,mech}$	rpm	1100	1100	
Maximum speed at the maximum torque	$n_{MAX,MMAX}$	rpm	120	270	
No-load speed	$n_{MAX,0}$	rpm	390	620	
Torque at n = rpm	M_0	Nm	166	166	
Current at M_0 and n = rpm	I_0	A	10	16	
Thermal standstill torque	M_0^*	Nm	118	118	
Thermal standstill current	I_0^*	A	7.1	11	
Physical constants					
Torque constant at 20 °C	$k_{T,20}$	Nm/A	16.6	10.5	
Voltage constant	k_E	V/(1000/min)	1007	634.3	
Motor constant at 20 °C	$k_{M,20}$	$Nm/\sqrt{W}$	3.33	3.34	
Thermal time constant	t_{TH}	s	60	60	
Pole pair No.	p	-	22	22	
Cogging torque	M_{COG}	Nm	1.7	1.7	
Stator weight	m_S	kg	8.6	8.6	
Rotor weight	m_L	kg	3.6	3.6	
Rotor moment of inertia	J_L	10^{-2} kgm^2	2.2	2.2	
Winding phase resistance at 20 °C	$R_{PH,20}$	Ω	5.98	2.36	
Winding phase inductance	L_{PH}	mH	21.2	8.4	
Data, main motor cooler					
Maximum dissipated thermal power	$Q_{H,MAX}$	W	2690	2670	
Recommended minimum flow rate	$\dot{V}_{H,MIN}$	l/min	4.1	4.1	
Temperature rise of the cooling medium	DT_H	K	9.4	9.4	
Pressure drop	Dp_H	bar	0.1	0.1	

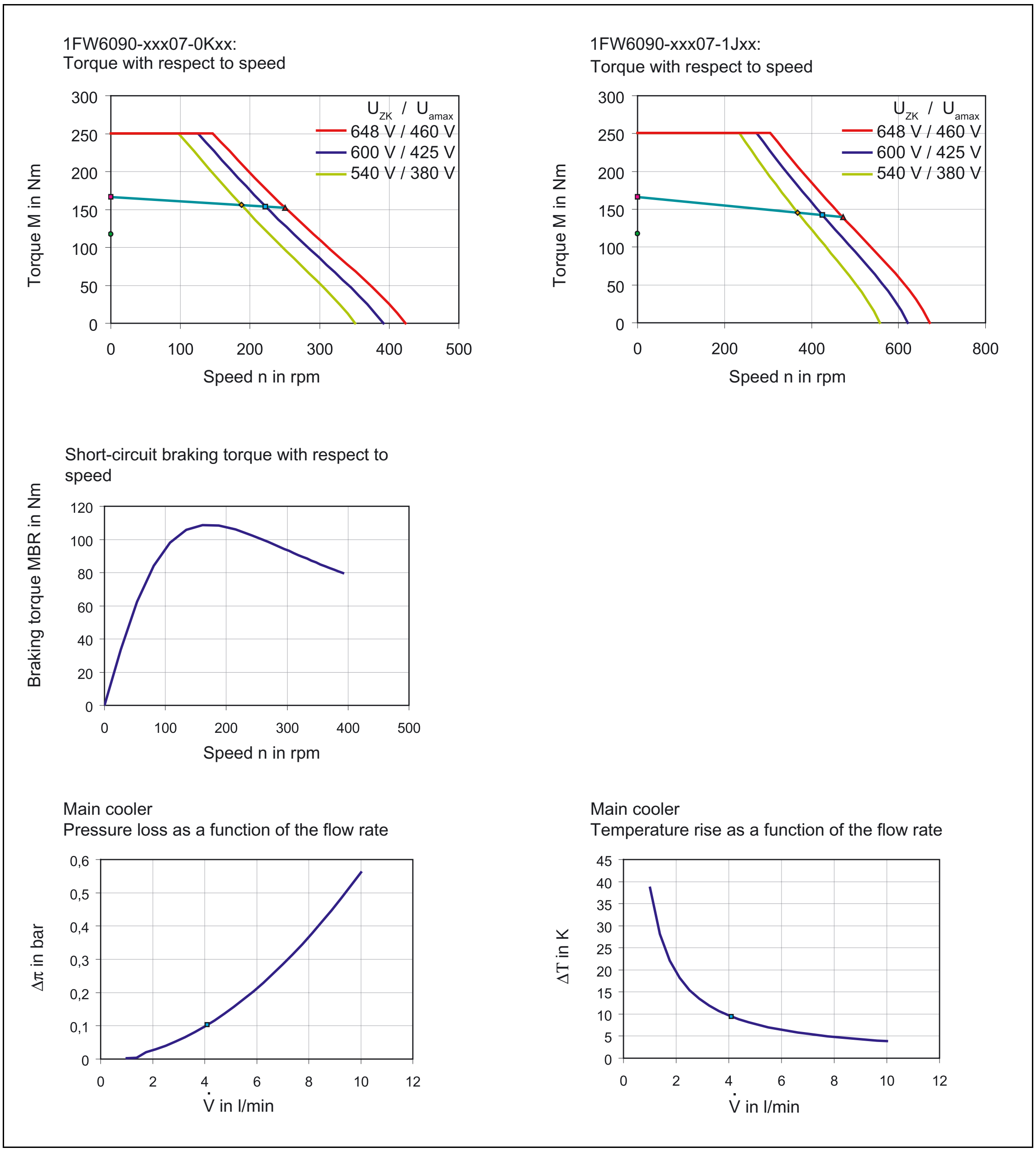


Figure 5-6: Characteristics for 1FW6090-xxx07-0Kxx, 1FW6090-xxx07-1Jxx

Table 5-4: 1FW6090-xxx10-0Kxx, 1FW6090-xxx10-1Jxx

1FW6090					
Technical Data	**Code**	**Units**	**-xxx10-0Kxx**	**-xxx10-1Jxx**	
Limitations					
DC link voltage	$V_{DC\ link}$	V	600	600	
Intake temperature of the water cooling	T_{INTAKE}	°C	35	35	
Rated temperature of the winding	T_N	°C	130	130	
Data at the rated operating point					
Rated torque	M_N	Nm	231	216	
Rated current	I_N	A	7.9	14	
Maximum speed at the rated torque	$n_{MAX,MN}$	rpm	82	270	
Rated power loss	$P_{V,N}$	W	3500	3500	
Limiting data					
Maximum torque	M_{MAX}	Nm	358	358	
Maximum current	I_{MAX}	A	13	26	
Electric power of the motor at M_{MAX}	$P_{EL,MAX}$	W	9430	15300	
Maximum mechanical speed	$n_{MAX,mech}$	rpm	1100	1100	
Maximum speed at the maximum torque	$n_{MAX,MMAX}$	rpm	8.7	170	
No-load speed	$n_{MAX,0}$	rpm	220	430	
Torque at n = rpm	M_0	Nm	238	238	
Current at M_0 and n = rpm	I_0	A	8.2	16	
Thermal standstill torque	M_0^*	Nm	168	168	
Thermal standstill current	I_0^*	A	5.6	11	
Physical constants					
Torque constant at 20 °C	$k_{T,20}$	Nm/A	30	15	
Voltage constant	k_E	V/(1000/min)	1812	906.2	
Motor constant at 20 °C	$k_{M,20}$	$Nm/\sqrt{W}$	4.17	4.17	
Thermal time constant	t_{TH}	s	60	60	
Pole pair No.	p	-	22	22	
Cogging torque	M_{COG}	Nm	2.4	2.4	
Stator weight	m_S	kg	12.1	12.1	
Rotor weight	m_L	kg	5.1	5.1	
Rotor moment of inertia	J_L	10^{-2} kgm^2	3.09	3.09	
Winding phase resistance at 20 °C	$R_{PH,20}$	Ω	12.4	3.09	
Winding phase inductance	L_{PH}	mH	47.5	11.9	
Data, main motor cooler					
Maximum dissipated thermal power	$Q_{H,MAX}$	W	3500	3500	
Recommended minimum flow rate	$\dot{V}_{H\ MIN}$	l/min	5.4	5.4	
Temperature rise of the cooling medium	DT_H	K	9.3	9.3	
Pressure drop	Dp_H	bar	0.4	0.4	

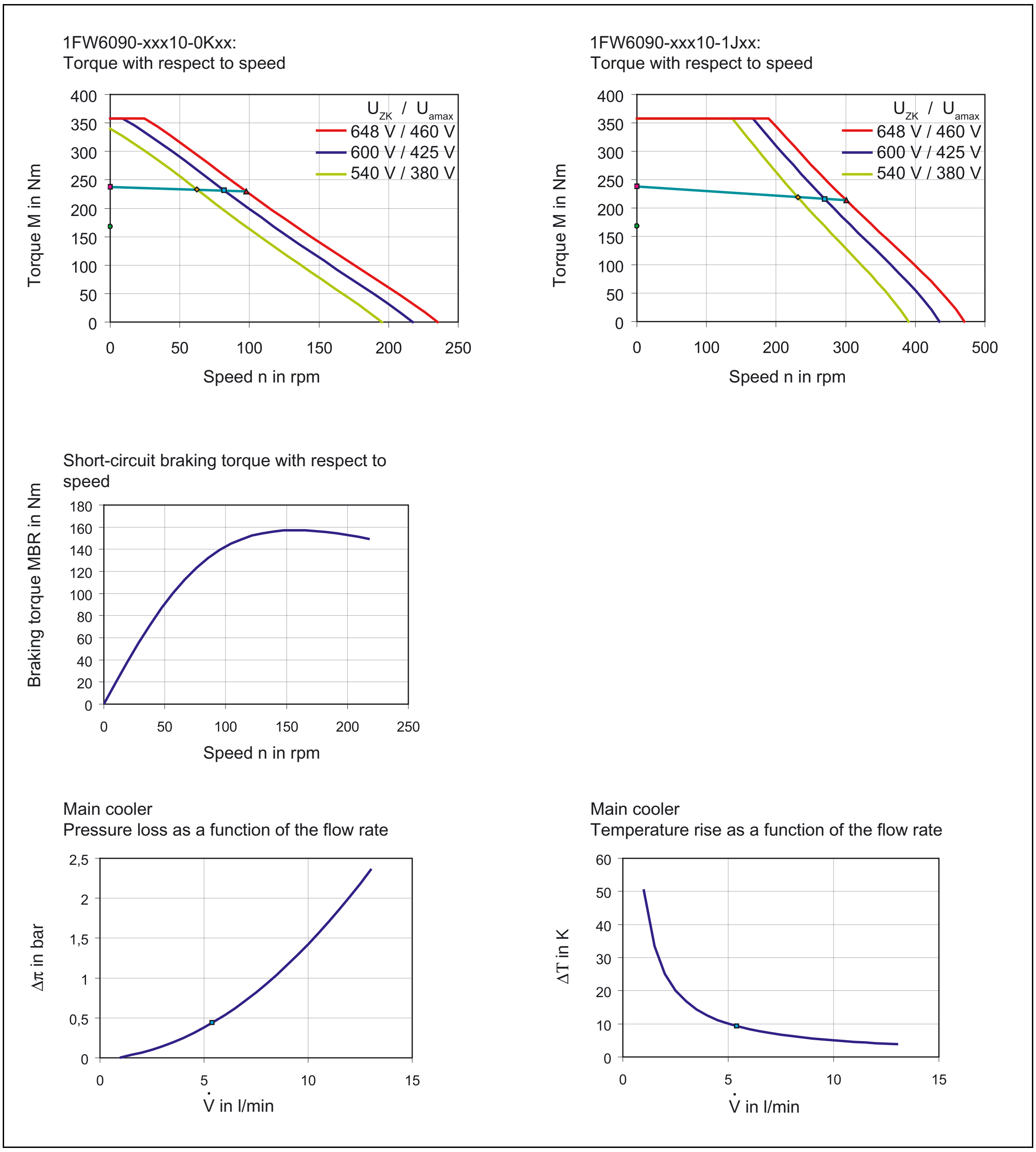


Figure 5-7: Characteristics for 1FW6090-xxx10-0Kxx, 1FW6090-xxx10-1Jxx

Table 5-5: 1FW6090-xxx15-1Jxx, 1FW6090-xxx15-2Jxx

1FW6090					
Technical Data	**Code**	**Units**	**-xxx15-1Jxx**	**-xxx15-2Jxx**	
Limitations					
DC link voltage	$V_{DC\ link}$	V	600	600	
Intake temperature of the water cooling	T_{INTAKE}	°C	35	35	
Rated temperature of the winding	T_N	°C	130	130	
Data at the rated operating point					
Rated torque	M_N	Nm	338	319	
Rated current	I_N	A	15	23	
Maximum speed at the rated torque	$n_{MAX,MN}$	rpm	150	310	
Rated power loss	$P_{V,N}$	W	4870	4960	
Limiting data					
Maximum torque	M_{MAX}	Nm	537	537	
Maximum current	I_{MAX}	A	26	43	
Electric power of the motor at M_{MAX}	$P_{EL,MAX}$	W	17100	24100	
Maximum mechanical speed	$n_{MAX,mech}$	rpm	1100	1100	
Maximum speed at the maximum torque	$n_{MAX,MMAX}$	rpm	78	200	
No-load speed	$n_{MAX,0}$	rpm	290	470	
Torque at n = rpm	M_0	Nm	357	357	
Current at M_0 and n = rpm	I_0	A	16	26	
Thermal standstill torque	M_0^*	Nm	252	252	
Thermal standstill current	I_0^*	A	11	18	
Physical constants					
Torque constant at 20 °C	$k_{T,20}$	Nm/A	22.5	13.7	
Voltage constant	k_E	V/(1000/min)	1359	831.3	
Motor constant at 20 °C	$k_{M,20}$	$Nm/\sqrt{W}$	5.3	5.25	
Thermal time constant	t_{TH}	s	60	60	
Pole pair No.	p	-	22	22	
Cogging torque	M_{COG}	Nm	3.6	3.6	
Stator weight	m_S	kg	19.5	19.5	
Rotor weight	m_L	kg	7.7	7.7	
Rotor moment of inertia	J_L	10^{-2} kgm^2	4.65	4.65	
Winding phase resistance at 20 °C	$R_{STR,20}$	Ω	4.3	1.64	
Winding phase inductance	L_{PH}	mH	17.7	6.6	
Data, main motor cooler					
Maximum dissipated thermal power	$Q_{H,MAX}$	W	4870	4960	
Recommended minimum flow rate	$\dot{V}_{H\ MIN}$	l/min	7	7	
Temperature rise of the cooling medium	DT_H	K	10	10.2	
Pressure drop	Dp_H	bar	0.6	0.6	

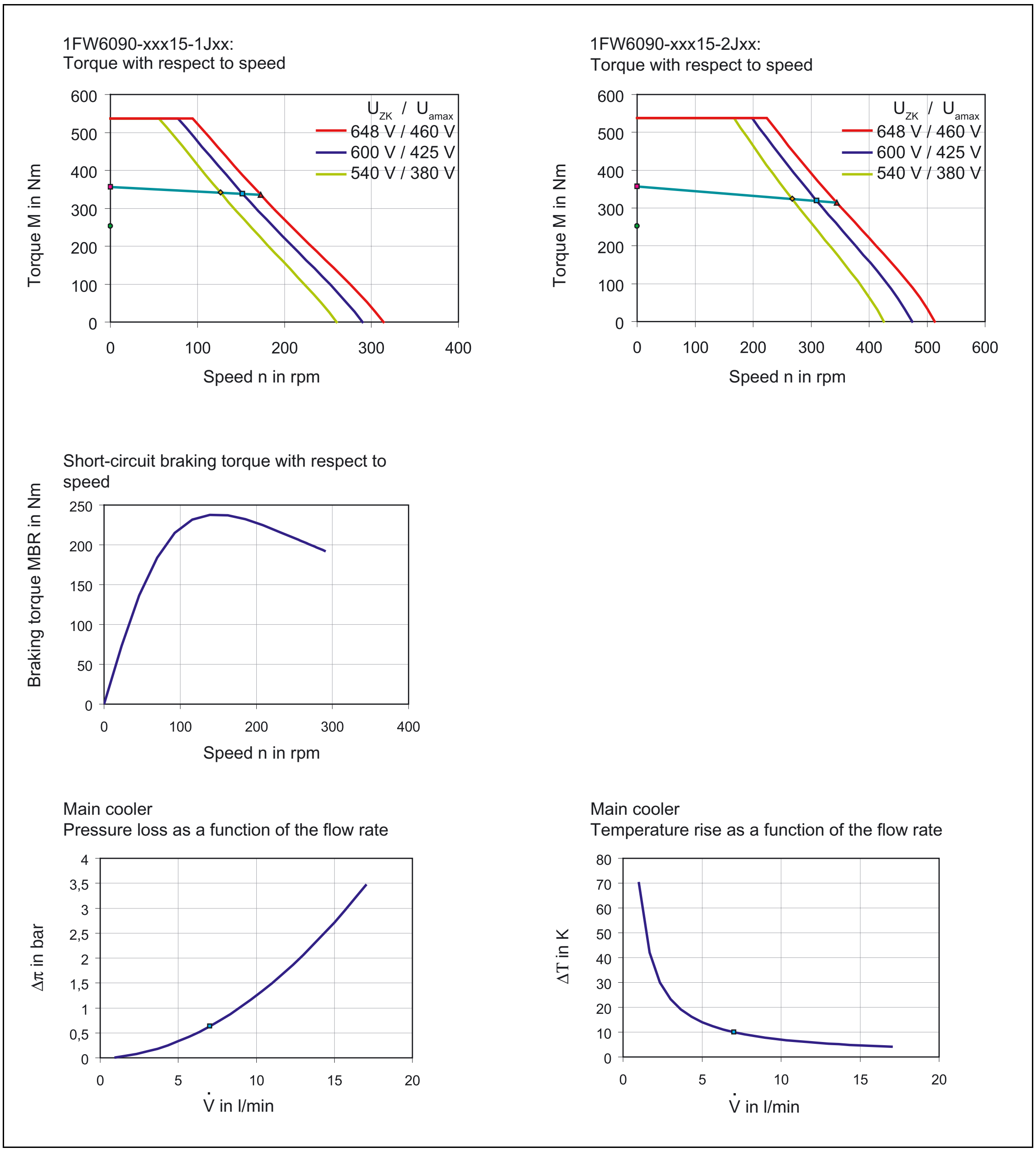


Figure 5-8: Characteristics for 1FW6090-xxx15-1Jxx, 1FW6090-xxx15-2Jxx

5.3.2 1FW6130-xxxxx-xxxx

Table 5-6: 1FW6130-xxx05-0Kxx, 1FW6130-xxx05-1Jxx

1FW6130					
Technical Data	**Code**	**Units**	**-xxx05-0Kxx**	**-xxx05-1Jxx**	
Limitations					
DC link voltage	$V_{DC\ link}$	V	600	600	
Intake temperature of the water cooling	T_{INTAKE}	°C	35	35	
Rated temperature of the winding	T_N	°C	130	130	
Data at the rated operating point					
Rated torque	M_N	Nm	241	217	
Rated current	I_N	A	9	14	
Maximum speed at the rated torque	$n_{MAX,MN}$	rpm	130	310	
Rated power loss	$P_{V,N}$	W	2930	2930	
Limiting data					
Maximum torque	M_{MAX}	Nm	439	439	
Maximum current	I_{MAX}	A	18	32	
Electric power of the motor at M_{MAX}	$P_{EL,MAX}$	W	12200	18300	
Maximum mechanical speed	$n_{MAX,mech}$	rpm	910	910	
Maximum speed at the maximum torque	$n_{MAX,MMAX}$	rpm	47	180	
No-load speed	$n_{MAX,0}$	rpm	240	420	
Torque at n = rpm	M_0	Nm	258	258	
Current at M_0 and n = rpm	I_0	A	9.7	17	
Thermal standstill torque	M_0^*	Nm	183	183	
Thermal standstill current	I_0^*	A	6.7	12	
Physical constants					
Torque constant at 20 °C	$k_{T,20}$	Nm/A	27.3	15.3	
Voltage constant	k_E	V/(1000/min)	1650	924.9	
Motor constant at 20 °C	$k_{M,20}$	$Nm/\sqrt{W}$	4.93	4.92	
Thermal time constant	t_{TH}	s	60	60	
Pole pair No.	p	-	33	33	
Cogging torque	M_{COG}	Nm	1.3	1.3	
Stator weight	m_S	kg	8.7	8.7	
Rotor weight	m_L	kg	4.5	4.5	
Rotor moment of inertia	J_L	10^{-2} kgm^2	6.37	6.37	
Winding phase resistance at 20 °C	$R_{STR,20}$	Ω	7.34	2.31	
Winding phase inductance	L_{PH}	mH	19.2	6	
Data, main motor cooler					
Maximum dissipated thermal power	$Q_{H,MAX}$	W	2930	2930	
Recommended minimum flow rate	$\dot{V}_{H\ MIN}$	l/min	4.1	4.1	
Temperature rise of the cooling medium	DT_H	K	10.3	10.3	
Pressure drop	Dp_H	bar	0.2	0.2	

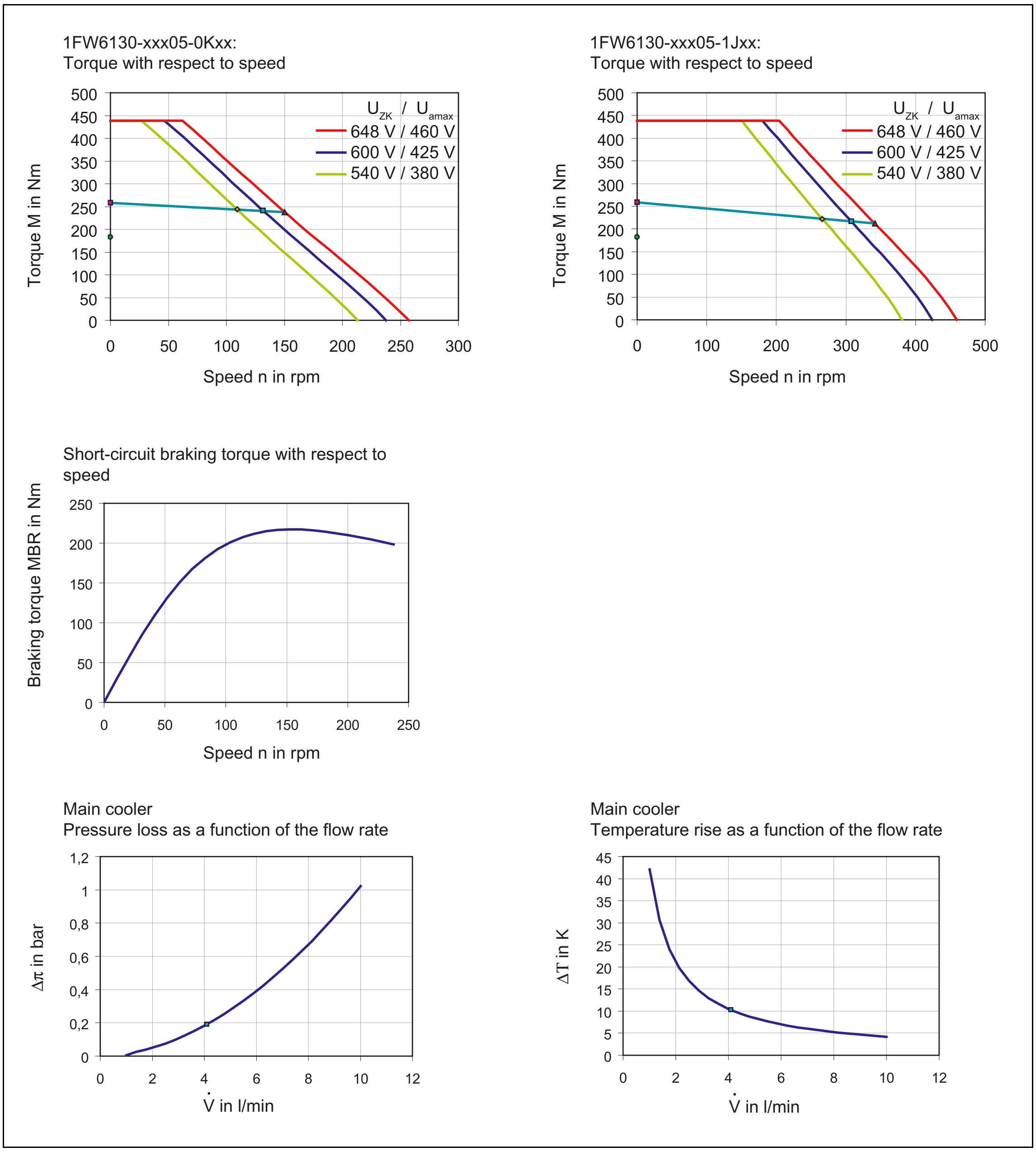


Figure 5-9: Characteristics for 1FW6130-xxx05-0Kxx, 1FW6130-xxx05-1Jxx

Table 5-7: 1FW6130-xxx07-0Kxx, 1FW6130-xxx07-1Jxx

1FW6130					
Technical Data	**Code**	**Units**	**-xxx07-0Kxx**	**-xxx07-1Jxx**	
Limitations					
DC link voltage	$V_{DC\ link}$	V	600	600	
Intake temperature of the water cooling	T_{INTAKE}	°C	35	35	
Rated temperature of the winding	T_N	°C	130	130	
Data at the rated operating point					
Rated torque	M_N	Nm	344	324	
Rated current	I_N	A	10	15	
Maximum speed at the rated torque	$n_{MAX,MN}$	rpm	96	200	
Rated power loss	$P_{V,N}$	W	3730	3710	
Limiting data					
Maximum torque	M_{MAX}	Nm	614	614	
Maximum current	I_{MAX}	A	20	32	
Electric power of the motor at M_{MAX}	$P_{EL,MAX}$	W	14200	19700	
Maximum mechanical speed	$n_{MAX,mech}$	rpm	910	910	
Maximum speed at the maximum torque	$n_{MAX,MMAX}$	rpm	21	110	
No-load speed	$n_{MAX,0}$	rpm	190	300	
Torque at n = rpm	M_0	Nm	361	361	
Current at M_0 and n = rpm	I_0	A	10	17	
Thermal standstill torque	M_0^*	Nm	256	256	
Thermal standstill current	I_0^*	A	7.6	12	
Physical constants					
Torque constant at 20 °C	$k_{T,20}$	Nm/A	34	21.4	
Voltage constant	k_E	V/(1000/min)	2056	1295	
Motor constant at 20 °C	$k_{M,20}$	$Nm/\sqrt{W}$	6.11	6.13	
Thermal time constant	t_{TH}	s	60	60	
Pole pair No.	p	-	33	33	
Cogging torque	M_{COG}	Nm	1.8	1.8	
Stator weight	m_S	kg	11.9	11.9	
Rotor weight	m_L	kg	6.3	6.3	
Rotor moment of inertia	J_L	10^{-2} kgm^2	8.92	8.92	
Winding phase resistance at 20 °C	$R_{STR,\ 20}$	Ω	7.41	2.92	
Winding phase inductance	L_{PH}	mH	21	8.3	
Data, main motor cooler					
Maximum dissipated thermal power	$Q_{H,MAX}$	W	3730	3710	
Recommended minimum flow rate	$\dot{V}_{H\ MIN}$	l/min	5.2	5.2	
Temperature rise of the cooling medium	DT_H	K	10.3	10.3	
Pressure drop	Dp_H	bar	0.3	0.3	

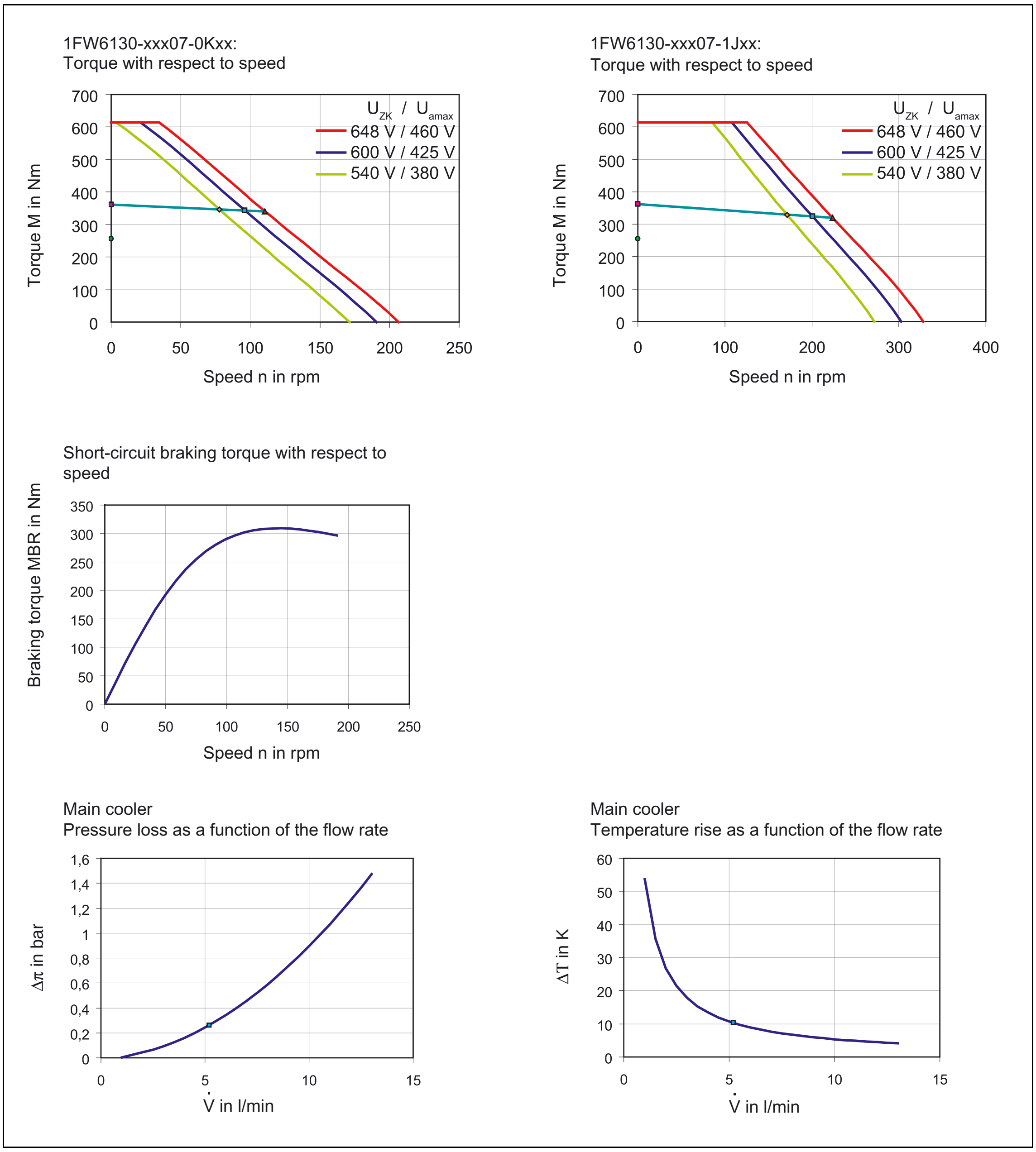


Figure 5-10: Characteristics for 1FW6130-xxx07-0Kxx, 1FW6130-xxx07-1Jxx

Table 5-8: 1FW6130-xxx10-1Jxx, 1FW6130-xxx10-2Jxx

1FW6130					
Technical Data	**Code**	**Units**	**-xxx10-1Jxx**	**-xxx10-2Jxx**	
Limitations					
DC link voltage	$V_{DC\ link}$	V	600	600	
Intake temperature of the water cooling	T_{INTAKE}	°C	35	35	
Rated temperature of the winding	T_N	°C	130	130	
Data at the rated operating point					
Rated torque	M_N	Nm	484	450	
Rated current	I_N	A	16	24	
Maximum speed at the rated torque	$n_{MAX,MN}$	rpm	120	250	
Rated power loss	$P_{V,N}$	W	4880	4980	
Limiting data					
Maximum torque	M_{MAX}	Nm	878	878	
Maximum current	I_{MAX}	A	32	53	
Electric power of the motor at M_{MAX}	$P_{EL,MAX}$	W	21400	30600	
Maximum mechanical speed	$n_{MAX,mech}$	rpm	910	910	
Maximum speed at the maximum torque	$n_{MAX,MMAX}$	rpm	50	150	
No-load speed	$n_{MAX,0}$	rpm	210	350	
Torque at n = rpm	M_0	Nm	516	516	
Current at M_0 and n = rpm	I_0	A	17	28	
Thermal standstill torque	M_0^*	Nm	365	365	
Thermal standstill current	I_0^*	A	12	19	
Physical constants					
Torque constant at 20 °C	$k_{T,20}$	Nm/A	30.6	18.6	
Voltage constant	k_E	V/(1000/min)	1850	1124	
Motor constant at 20 °C	$k_{M,20}$	$Nm/\sqrt{W}$	7.63	7.55	
Thermal time constant	t_{TH}	s	60	60	
Pole pair No.	p	-	33	33	
Cogging torque	M_{COG}	Nm	2.6	2.6	
Stator weight	m_S	kg	16.2	16.2	
Rotor weight	m_L	kg	9	9	
Rotor moment of inertia	J_L	10^{-2} kgm^2	12.7	12.7	
Winding phase resistance at 20 °C	$R_{STR,20}$	Ω	3.84	1.45	
Winding phase inductance	L_{PH}	mH	11.7	4.3	
Data, main motor cooler					
Maximum dissipated thermal power	$Q_{H,MAX}$	W	4880	4980	
Recommended minimum flow rate	$\dot{V}_{H\ MIN}$	l/min	7	7	
Temperature rise of the cooling medium	DT_H	K	10	10.2	
Pressure drop	Dp_H	bar	1.1	1.1	

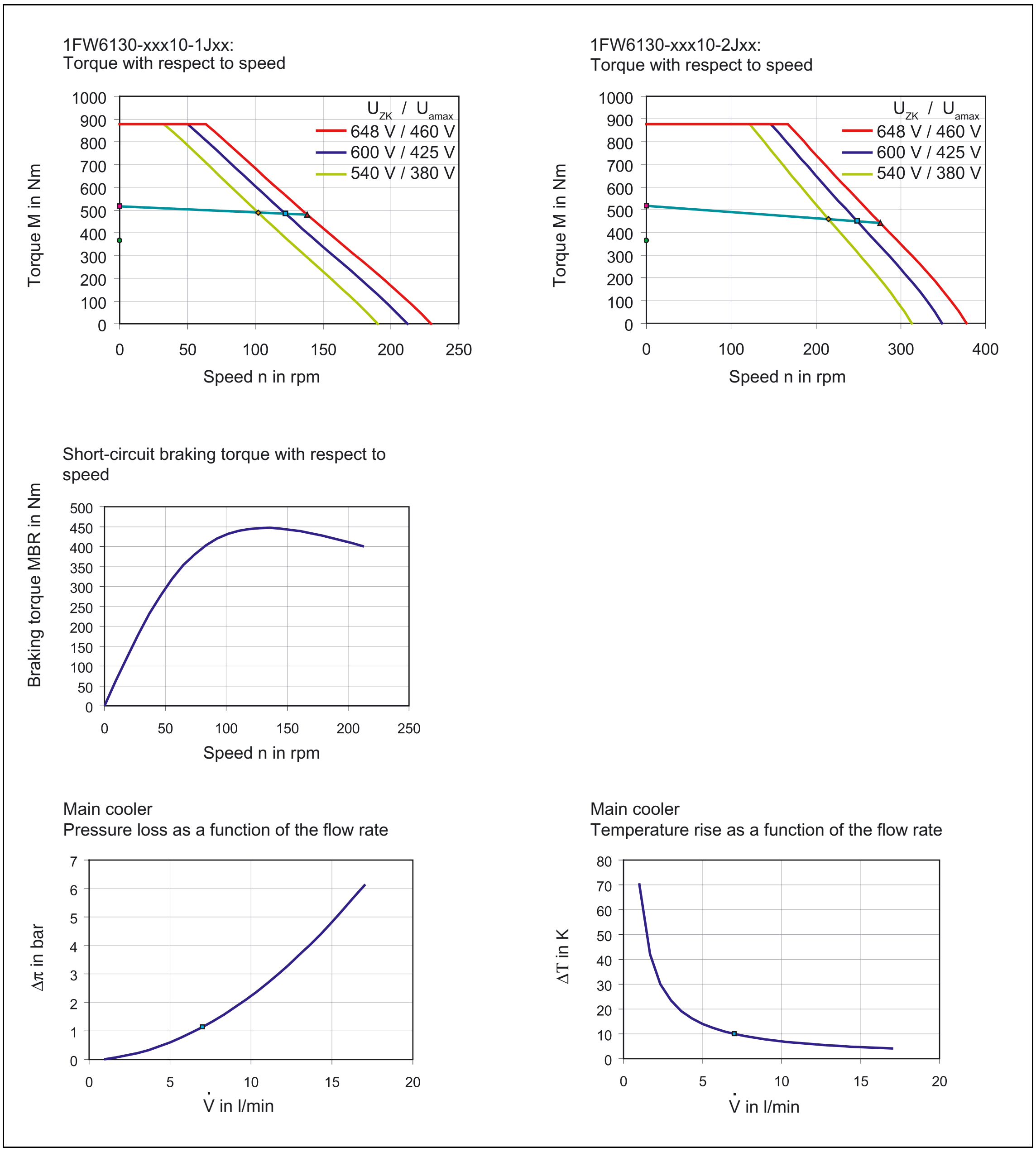


Figure 5-11: Characteristics for 1FW6130-xxx10-1Jxx, 1FW6130-xxx10-2Jxx

Table 5-9: 1FW6130-xxx15-1Jxx, 1FW6130-xxx15-2Jxx

1FW6130					
Technical Data	**Code**	**Units**	**-xxx15-1Jxx**	**-xxx15-2Jxx**	
Limitations					
DC link voltage	$V_{DC\ link}$	V	600	600	
Intake temperature of the water cooling	T_{INTAKE}	°C	35	35	
Rated temperature of the winding	T_N	°C	130	130	
Data at the rated operating point					
Rated torque	M_N	Nm	744	714	
Rated current	I_N	A	18	26	
Maximum speed at the rated torque	$n_{MAX,MN}$	rpm	78	150	
Rated power loss	$P_{V,N}$	W	6810	6810	
Limiting data					
Maximum torque	M_{MAX}	Nm	1320	1320	
Maximum current	I_{MAX}	A	36	54	
Electric power of the motor at M_{MAX}	$P_{EL,MAX}$	W	25400	34100	
Maximum mechanical speed	$n_{MAX,mech}$	rpm	910	910	
Maximum speed at the maximum torque	$n_{MAX,MMAX}$	rpm	14	77	
No-load speed	$n_{MAX,0}$	rpm	160	240	
Torque at n = rpm	M_0	Nm	775	775	
Current at M_0 and n = rpm	I_0	A	19	29	
Thermal standstill torque	M_0^*	Nm	548	548	
Thermal standstill current	I_0^*	A	13	20	
Physical constants					
Torque constant at 20 °C	$k_{T,20}$	Nm/A	40.9	27.3	
Voltage constant	k_E	V/(1000/min)	2475	1650	
Motor constant at 20 °C	$k_{M,20}$	$Nm/\sqrt{W}$	9.69	9.69	
Thermal time constant	t_{TH}	s	60	60	
Pole pair No.	p	-	33	33	
Cogging torque	M_{COG}	Nm	3.9	3.9	
Stator weight	m_S	kg	24.7	24.7	
Rotor weight	m_L	kg	13.5	13.5	
Rotor moment of inertia	J_L	10^{-2} kgm^2	19.1	19.1	
Winding phase resistance at 20 °C	$R_{STR,20}$	Ω	4.27	1.9	
Winding phase inductance	L_{PH}	mH	13.9	6.2	
Data, main motor cooler					
Maximum dissipated thermal power	$Q_{H,MAX}$	W	6810	6810	
Recommended minimum flow rate	$\dot{V}_{H\ MIN}$	l/min	9.8	9.8	
Temperature rise of the cooling medium	DT_H	K	10	10	
Pressure drop	Dp_H	bar	1.9	1.9	

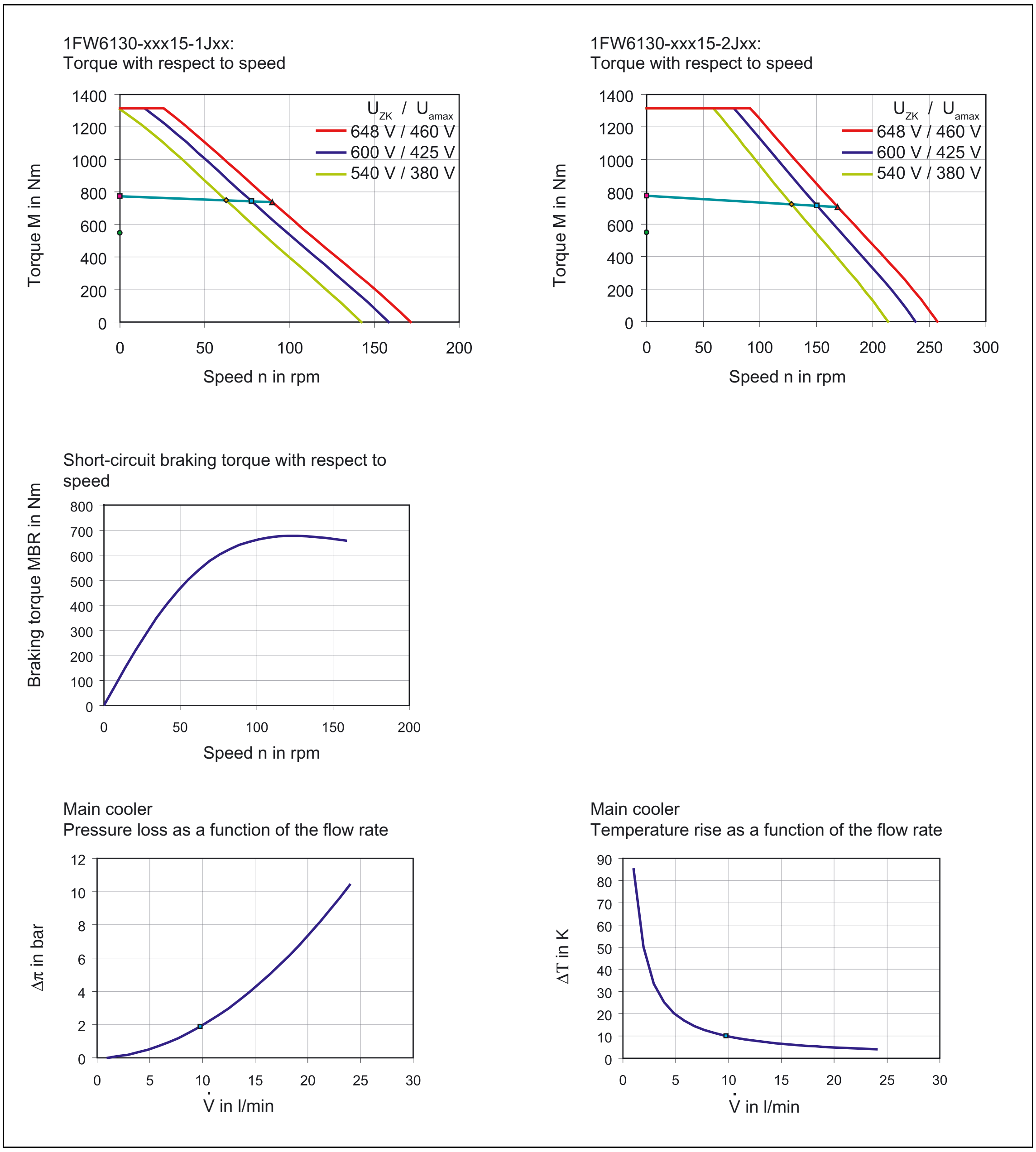


Figure 5-12: Characteristics for 1FW6130-xxx15-1Jxx, 1FW6130-xxx15-2Jxx

5.3.3 1FW6160-xxxxx-xxxx

Table 5-10: 1FW6160-xxx05-1Jxx, 1FW6160-xxx05-2Jxx

1FW6160					
Technical Data	**Code**	**Units**	**-xxx05-1Jxx**	**-xxx05-2Jxx**	
Limitations					
DC link voltage	$V_{DC\ link}$	V	600	600	
Intake temperature of the water cooling	T_{INTAKE}	°C	35	35	
Rated temperature of the winding	T_N	°C	130	130	
Data at the rated operating point					
Rated torque	M_N	Nm	431	404	
Rated current	I_N	A	16	24	
Maximum speed at the rated torque	$n_{MAX,MN}$	rpm	140	250	
Rated power loss	$P_{V,N}$	W	2840	2850	
Limiting data					
Maximum torque	M_{MAX}	Nm	716	716	
Maximum current	I_{MAX}	A	31	49	
Electric power of the motor at M_{MAX}	$P_{EL,MAX}$	W	15100	20000	
Maximum mechanical speed	$n_{MAX,mech}$	rpm	690	690	
Maximum speed at the maximum torque	$n_{MAX,MMAX}$	rpm	84	150	
No-load speed	$n_{MAX,0}$	rpm	240	380	
Torque at n = rpm	M_0	Nm	467	467	
Current at M_0 and n = rpm	I_0	A	17	28	
Thermal standstill torque	M_0^*	Nm	330	330	
Thermal standstill current	I_0^*	A	12	19	
Physical constants					
Torque constant at 20 °C	$k_{T,20}$	Nm/A	26.6	17	
Voltage constant	k_E	V/(1000/min)	1608	1029	
Motor constant at 20 °C	$k_{M,20}$	$Nm/\sqrt{W}$	8.96	8.95	
Thermal time constant	t_{TH}	s	180	180	
Pole pair No.	p	-	35	35	
Cogging torque	M_{COG}	Nm	2.3	2.3	
Stator weight	m_S	kg	27.2	27.2	
Rotor weight	m_L	kg	9.1	9.1	
Rotor moment of inertia	J_L	10^{-2} kgm^2	19	19	
Winding phase resistance at 20 °C	$R_{STR,20}$	Ω	2.11	0.866	
Winding phase inductance	L_{PH}	mH	18.1	7.4	
Data, main motor cooler					
Maximum dissipated thermal power	$Q_{H,MAX}$	W	2200	2210	
Recommended minimum flow rate	$\dot{V}_{H\ MIN}$	l/min	4.4	4.4	
Temperature rise of the cooling medium	DT_H	K	7.2	7.3	
Pressure drop	Dp_H	bar	0.2	0.2	
Data, precision motor cooler					
Maximum dissipated thermal power	$Q_{P,MAX}$	W	644	647	
Recommended minimum flow rate	$\dot{V}_{P\ MIN}$	l/min	0.9	0.9	
Temperature rise of the cooling medium	DT_P	K	9.9	10	
Pressure drop	Dp_P	bar	0.2	0.2	

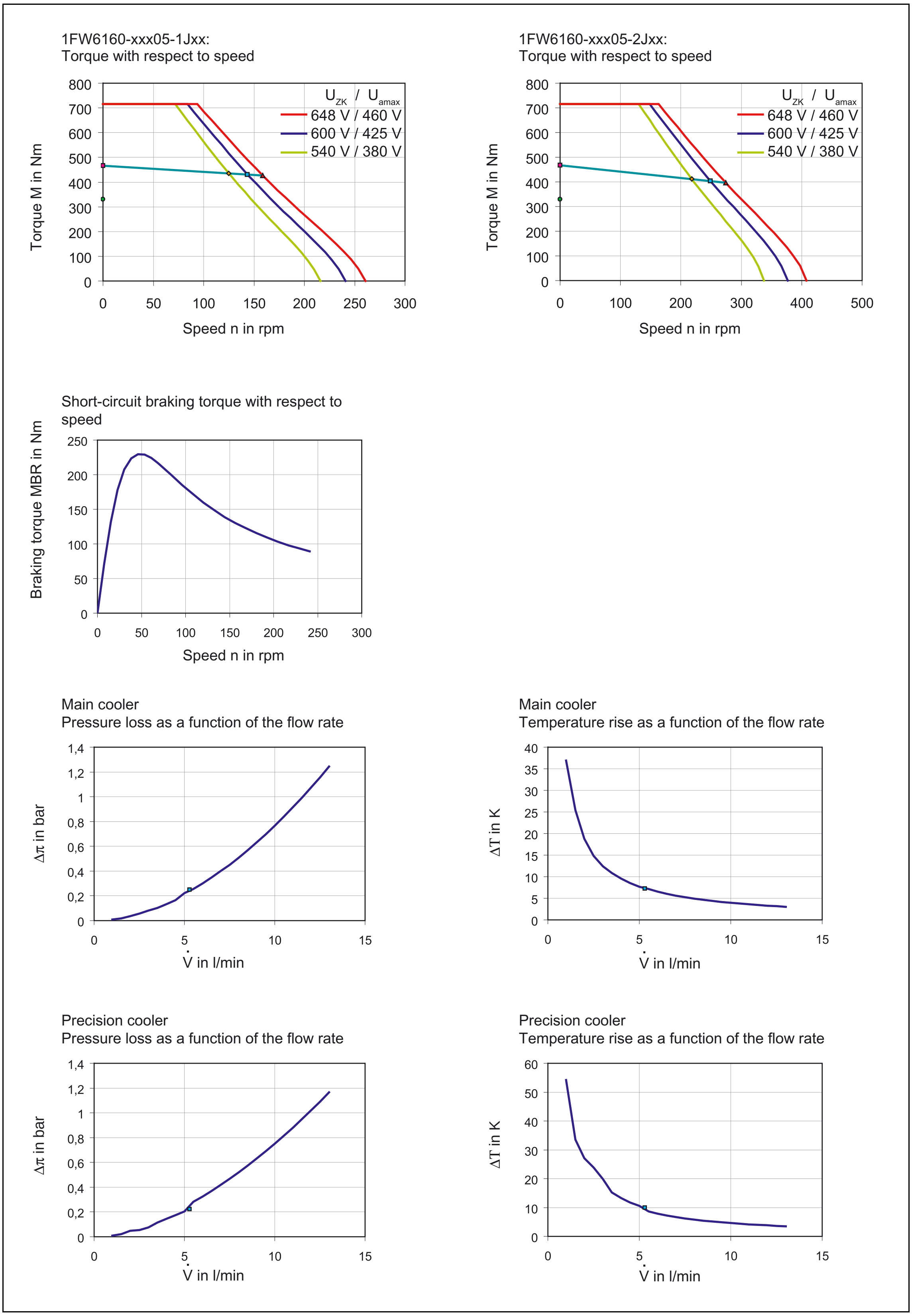


Figure 5-13: Characteristics for 1FW6160-xxx05-1Jxx, 1FW6160-xxx05-2Jxx

Table 5-11: 1FW6160 xxx07-1Jxx, 1FW6160-xxx07-2Jxx

1FW6160					
Technical Data	**Code**	**Units**	**-xxx07-1Jxx**	**-xxx07-2Jxx**	
Limitations					
DC link voltage	$V_{DC\ link}$	V	600	600	
Intake temperature of the water cooling	T_{INTAKE}	°C	35	35	
Rated temperature of the winding	T_N	°C	130	130	
Data at the rated operating point					
Rated torque	M_N	Nm	620	594	
Rated current	I_N	A	16	25	
Maximum speed at the rated torque	$n_{MAX,MN}$	rpm	96	170	
Rated power loss	$P_{V,N}$	W	3590	3610	
Limiting data					
Maximum torque	M_{MAX}	Nm	1000	1000	
Maximum current	I_{MAX}	A	31	49	
Electric power of the motor at M_{MAX}	$P_{EL,MAX}$	W	16700	21800	
Maximum mechanical speed	$n_{MAX,mech}$	rpm	690	690	
Maximum speed at the maximum torque	$n_{MAX,MMAX}$	rpm	53	100	
No-load speed	$n_{MAX,0}$	rpm	170	270	
Torque at n = rpm	M_0	Nm	653	653	
Current at M_0 and n = rpm	I_0	A	17	28	
Thermal standstill torque	M_0^*	Nm	462	462	
Thermal standstill current	I_0^*	A	12	19	
Physical constants					
Torque constant at 20 °C	$k_{T,20}$	Nm/A	37.2	23.8	
Voltage constant	k_E	V/(1000/min)	2251	1441	
Motor constant at 20 °C	$k_{M,20}$	$Nm/\sqrt{W}$	11.2	11.1	
Thermal time constant	t_{TH}	s	180	180	
Pole pair No.	p	-	35	35	
Cogging torque	M_{COG}	Nm	3.3	3.3	
Stator weight	m_S	kg	36.2	36.2	
Rotor weight	m_L	kg	12.1	12.1	
Rotor moment of inertia	J_L	10^{-2} kgm^2	25.8	25.8	
Winding phase resistance at 20 °C	$R_{STR,20}$	Ω	2.66	1.09	
Winding phase inductance	L_{PH}	mH	25.1	10.3	
Data, main motor cooler					
Maximum dissipated thermal power	$Q_{H,MAX}$	W	2970	2990	
Recommended minimum flow rate	$\dot{V}_{H\ MIN}$	l/min	5.3	5.3	
Temperature rise of the cooling medium	DT_H	K	8	8.1	
Pressure drop	Dp_H	bar	0.4	0.4	
Data, precision motor cooler					
Maximum dissipated thermal power	$Q_{P,MAX}$	W	618	620	
Recommended minimum flow rate	$\dot{V}_{P\ MIN}$	l/min	1.3	1.3	
Temperature rise of the cooling medium	DT_P	K	7	7	
Pressure drop	Dp_P	bar	0.4	0.4	

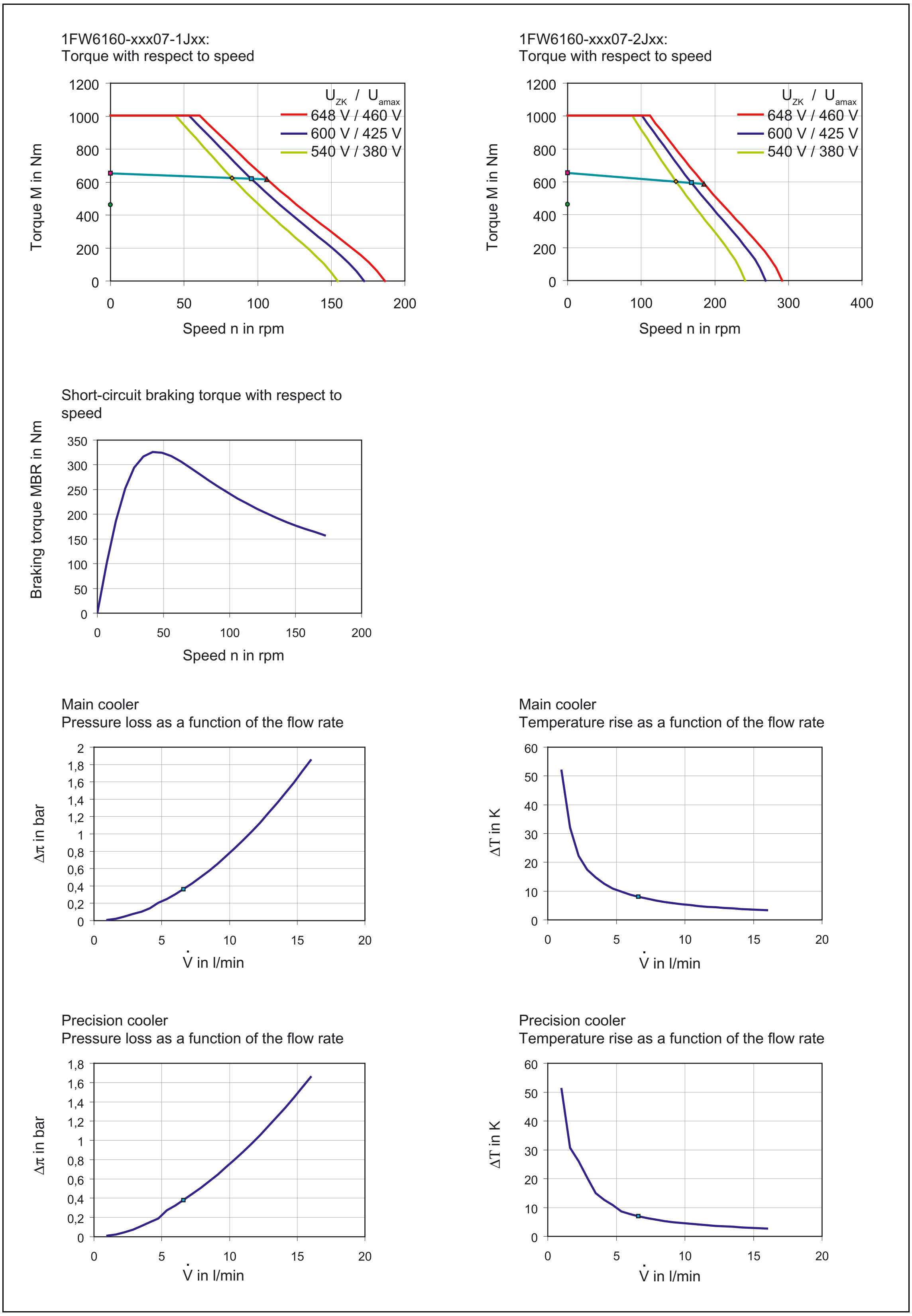
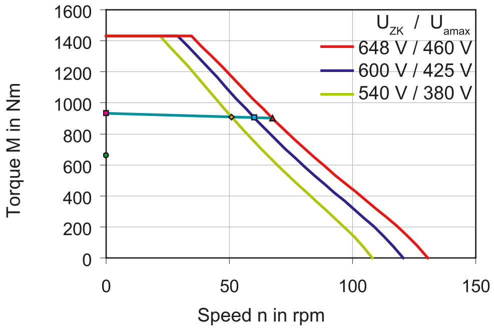


Figure 5-14: Characteristics for 1FW6160-xxx07-1Jxx, 1FW6160-xxx07-2Jxx

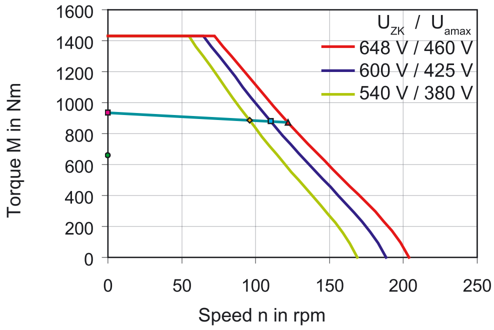
Table 5-12: 1FW6160-xxx10-1Jxx, 1FW6160-xxx10-2Jxx

1FW6160					
Technical Data	**Code**	**Units**	**-xxx10-1Jxx**	**-xxx10-2Jxx**	
Limitations					
DC link voltage	$V_{DC\ link}$	V	600	600	
Intake temperature of the water cooling	T_{INTAKE}	°C	35	35	
Rated temperature of the winding	T_N	°C	130	130	
Data at the rated operating point					
Rated torque	M_N	Nm	903	878	
Rated current	I_N	A	17	26	
Maximum speed at the rated torque	$n_{MAX,MN}$	rpm	60	110	
Rated power loss	$P_{V,N}$	W	4720	4740	
Limiting data					
Maximum torque	M_{MAX}	Nm	1430	1430	
Maximum current	I_{MAX}	A	31	49	
Electric power of the motor at M_{MAX}	$P_{EL,MAX}$	W	19000	24400	
Maximum mechanical speed	$n_{MAX,mech}$	rpm	690	690	
Maximum speed at the maximum torque	$n_{MAX,MMAX}$	rpm	29	65	
No-load speed	$n_{MAX,0}$	rpm	120	190	
Torque at n = rpm	M_0	Nm	933	933	
Current at M_0 and n = rpm	I_0	A	17	28	
Thermal standstill torque	M_0^*	Nm	660	660	
Thermal standstill current	I_0^*	A	12	19	
Physical constants					
Torque constant at 20 °C	$k_{T,20}$	Nm/A	53.2	34	
Voltage constant	k_E	V/(1000/min)	3216	2058	
Motor constant at 20 °C	$k_{M,20}$	$Nm/\sqrt{W}$	13.9	13.9	
Thermal time constant	t_{TH}	s	180	180	
Pole pair No.	p	-	35	35	
Cogging torque	M_{COG}	Nm	4.7	4.7	
Stator weight	m_S	kg	49	49	
Rotor weight	m_L	kg	17.3	17.3	
Rotor moment of inertia	J_L	10^{-2} kgm^2	36	36	
Winding phase resistance at 20 °C	$R_{STR,20}$	Ω	3.49	1.44	
Winding phase inductance	L_{PH}	mH	35.5	14.5	
Data, main motor cooler					
Maximum dissipated thermal power	$Q_{H,MAX}$	W	4120	4140	
Recommended minimum flow rate	$\dot{V}_{H\ MIN}$	l/min	7.2	7.2	
Temperature rise of the cooling medium	DT_H	K	8.2	8.3	
Pressure drop	Dp_H	bar	0.6	0.6	
Data, precision motor cooler					
Maximum dissipated thermal power	$Q_{P,MAX}$	W	595	598	
Recommended minimum flow rate	$\dot{V}_{P\ MIN}$	l/min	1.7	1.7	
Temperature rise of the cooling medium	DT_P	K	5	5.1	
Pressure drop	Dp_P	bar	0.6	0.6	

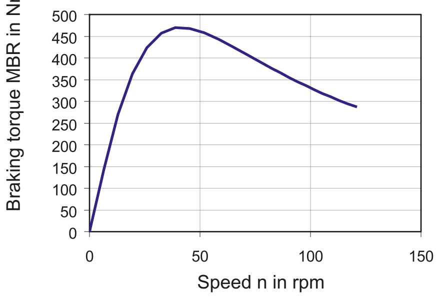
1FW6160-xxx10-1Jxx:
Torque with respect to speed



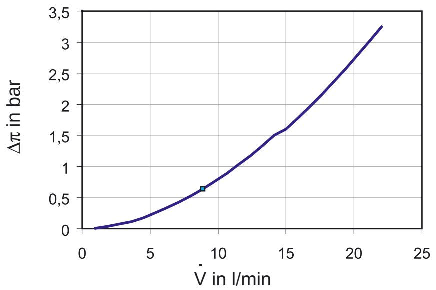
1FW6160-xxx10-2Jxx:
Torque with respect to speed



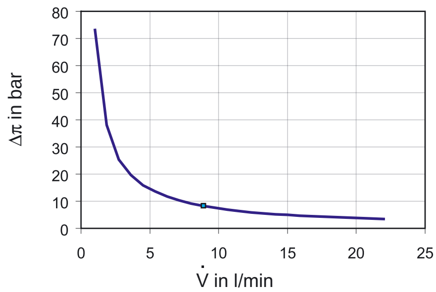
Short-circuit braking torque with respect to speed



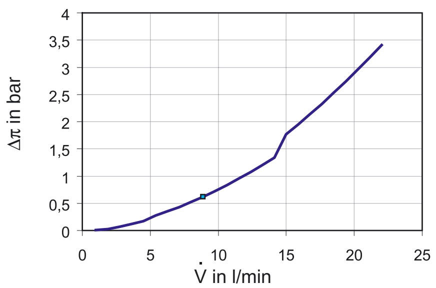
Main cooler
Pressure loss as a function of the flow rate



Main cooler
Temperature rise as a function of the flow rate



Precision cooler
Pressure loss as a function of the flow rate



Precision cooler
Temperature rise as a function of the flow rate

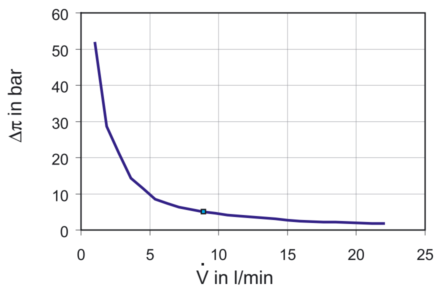


Figure 5-15: Characteristics for 1FW6160-xxx10-1Jxx, 1FW6160-xxx10-2Jxx

Table 5-13: 1FW6160-xxx15-2Jxx, 1FW6160-xxx15-5Gxx

1FW6160					
Technical Data	**Code**	**Units**	**-xxx15-2Jxx**	**-xxx15-5Gxx**	
Limitations					
DC link voltage	$V_{DC\ link}$	V	600	600	
Intake temperature of the water cooling	T_{INTAKE}	°C	35	35	
Rated temperature of the winding	T_N	°C	130	130	
Data at the rated operating point					
Rated torque	M_N	Nm	1350	1280	
Rated current	I_N	A	26	50	
Maximum speed at the rated torque	$n_{MAX,MN}$	rpm	66	160	
Rated power loss	$P_{V,N}$	W	6620	6670	
Limiting data					
Maximum torque	M_{MAX}	Nm	2150	2150	
Maximum current	I_{MAX}	A	49	98	
Electric power of the motor at M_{MAX}	$P_{EL,MAX}$	W	28200	42600	
Maximum mechanical speed	$n_{MAX,mech}$	rpm	690	690	
Maximum speed at the maximum torque	$n_{MAX,MMAX}$	rpm	34	97	
No-load speed	$n_{MAX,0}$	rpm	130	250	
Torque at n = rpm	M_0	Nm	1400	1400	
Current at M_0 and n = rpm	I_0	A	28	56	
Thermal standstill torque	M_0^*	Nm	990	990	
Thermal standstill current	I_0^*	A	19	38	
Physical constants					
Torque constant at 20 °C	$k_{T,20}$	Nm/A	51.1	25.5	
Voltage constant	k_E	V/(1000/min)	3087	1544	
Motor constant at 20 °C	$k_{M,20}$	$Nm/\sqrt{W}$	17.6	17.6	
Thermal time constant	t_{TH}	s	180	180	
Pole pair No.	p	-	35	35	
Cogging torque	M_{COG}	Nm	7	7	
Stator weight	m_S	kg	69.8	69.8	
Rotor weight	m_L	kg	25.5	25.5	
Rotor moment of inertia	J_L	10^{-2} kgm^2	53.1	53.1	
Winding phase resistance at 20 °C	$R_{STR,20}$	Ω	2.01	0.506	
Winding phase inductance	L_{PH}	mH	21.7	5.4	
Data, main motor cooler					
Maximum dissipated thermal power	$Q_{H,MAX}$	W	6030	6080	
Recommended minimum flow rate	$\dot{V}_{H\ MIN}$	l/min	9.9	9.9	
Temperature rise of the cooling medium	DT_H	K	8.8	8.9	
Pressure drop	Dp_H	bar	1.2	1.2	
Data, precision motor cooler					
Maximum dissipated thermal power	$Q_{P,MAX}$	W	588	593	
Recommended minimum flow rate	$\dot{V}_{P\ MIN}$	l/min	2.6	2.6	
Temperature rise of the cooling medium	DT_P	K	3.2	3.3	
Pressure drop	Dp_P	bar	1.3	1.3	

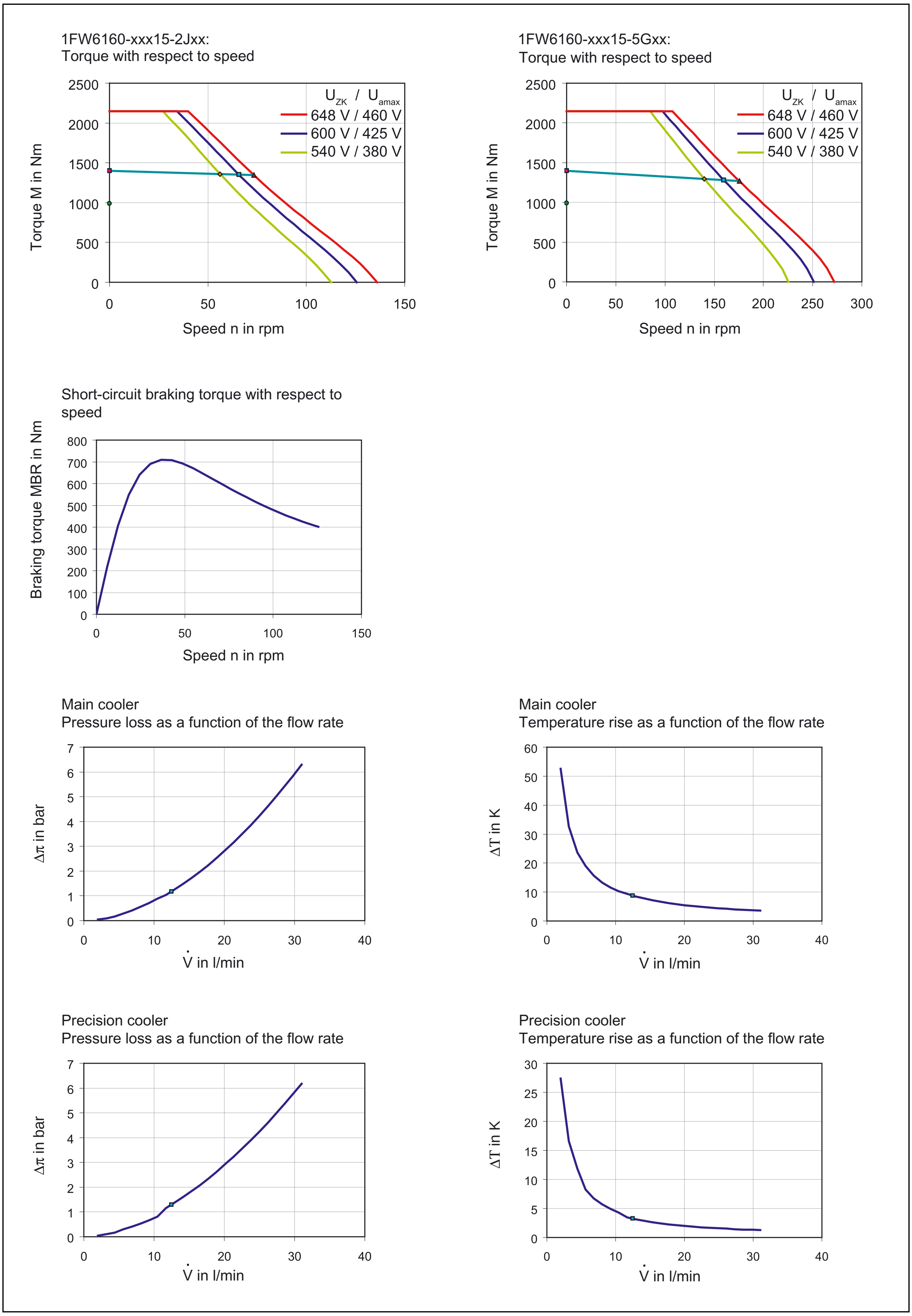


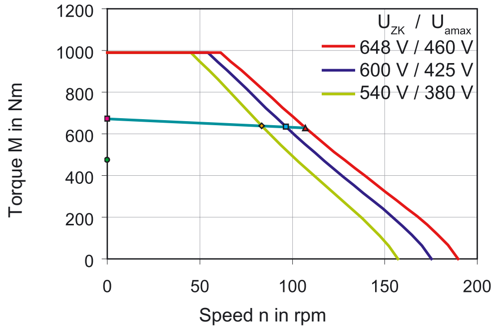
Figure 5-16: Characteristics for 1FW6160-xxx15-2Jxx, 1FW6160-xxx15-5Gxx

5.3.4 1FW6190-xxxxx-xxxx

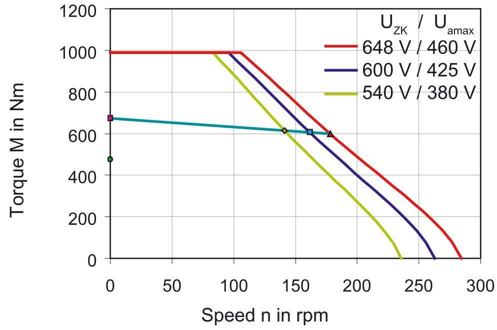
Table 5-14: 1FW6190-xxx05-1Jxx, 1FW6190-xxx05-2Jxx

1FW6190					
Technical Data	**Code**	**Units**	**-xxx05-1Jxx**	**-xxx05-2Jxx**	
Limitations					
DC link voltage	$V_{DC\ link}$	V	600	600	
Intake temperature of the water cooling	T_{INTAKE}	°C	35	35	
Rated temperature of the winding	T_N	°C	130	130	
Data at the rated operating point					
Rated torque	M_N	Nm	633	605	
Rated current	I_N	A	17	24	
Maximum speed at the rated torque	$n_{MAX,MN}$	rpm	97	160	
Rated power loss	$P_{V,N}$	W	3510	3510	
Limiting data					
Maximum torque	M_{MAX}	Nm	990	990	
Maximum current	I_{MAX}	A	31	47	
Electric power of the motor at M_{MAX}	$P_{EL,MAX}$	W	16300	20600	
Maximum mechanical speed	$n_{MAX,mech}$	rpm	630	630	
Maximum speed at the maximum torque	$n_{MAX,MMAX}$	rpm	54	96	
No-load speed	$n_{MAX,0}$	rpm	180	260	
Torque at n = rpm	M_0	Nm	672	672	
Current at M_0 and n = rpm	I_0	A	18	27	
Thermal standstill torque	M_0^*	Nm	475	475	
Thermal standstill current	I_0^*	A	12	18	
Physical constants					
Torque constant at 20 °C	$k_{T,20}$	Nm/A	38.7	25.8	
Voltage constant	k_E	V/(1000/min)	2338	1559	
Motor constant at 20 °C	$k_{M,20}$	$Nm/\sqrt{W}$	11.9	11.9	
Thermal time constant	t_{TH}	s	180	180	
Pole pair No.	p	-	42	42	
Cogging torque	M_{COG}	Nm	3.4	3.4	
Stator weight	m_S	kg	32.1	32.1	
Rotor weight	m_L	kg	10.7	10.7	
Rotor moment of inertia	J_L	10^{-2} kgm^2	35.8	35.8	
Winding phase resistance at 20 °C	$R_{STR,20}$	Ω	2.53	1.12	
Winding phase inductance	L_{PH}	mH	21.5	9.6	
Data, main motor cooler					
Maximum dissipated thermal power	$Q_{H,MAX}$	W	2730	2730	
Recommended minimum flow rate	$\dot{V}_{H\ MIN}$	l/min	5.7	5.7	
Temperature rise of the cooling medium	DT_H	K	7	7	
Pressure drop	Dp_H	bar	0.4	0.4	
Data, precision motor cooler					
Maximum dissipated thermal power	$Q_{P,MAX}$	W	777	777	
Recommended minimum flow rate	$\dot{V}_{P\ MIN}$	l/min	1.3	1.3	
Temperature rise of the cooling medium	DT_P	K	8.3	8.3	
Pressure drop	Dp_P	bar	0.4	0.4	

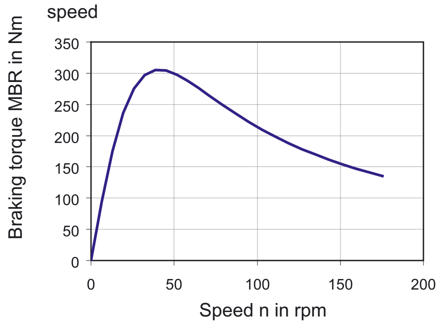
1FW6190-xxx05-1Jxx:
Torque with respect to speed



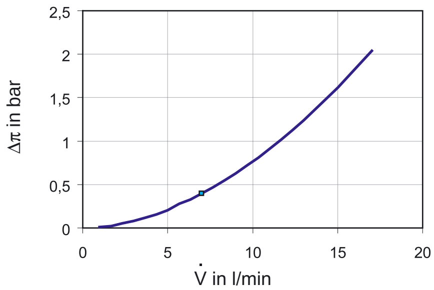
1FW6190-xxx05-2Jxx:
Torque with respect to speed



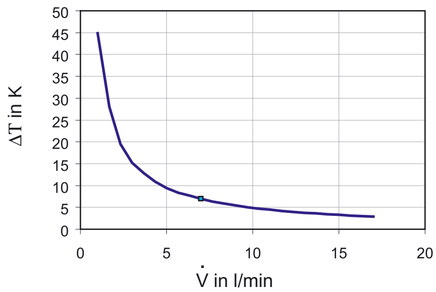
Short-circuit braking torque with respect to speed



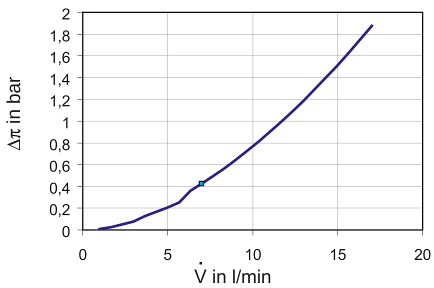
Main cooler
Pressure loss as a function of the flow rate



Main cooler
Temperature rise as a function of the flow rate



Precision cooler
Pressure loss as a function of the flow rate



Precision cooler
Temperature rise as a function of the flow rate

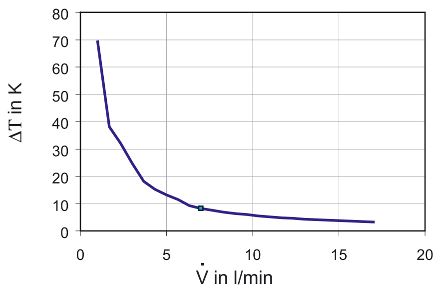


Figure 5-17: Characteristics for 1FW6190-xxx05-1Jxx, 1FW6190-xxx05-2Jxx

Table 5-15: 1FW6190-xxx07-1Jxx, 1FW6190-xxx07-2Jxx

1FW6190					
Technical Data	**Code**	**Units**	**-xxx07-1Jxx**	**-xxx07-2Jxx**	
Limitations					
DC link voltage	$V_{DC\ link}$	V	600	600	
Intake temperature of the water cooling	T_{INTAKE}	°C	35	35	
Rated temperature of the winding	T_N	°C	130	130	
Data at the rated operating point					
Rated torque	M_N	Nm	905	879	
Rated current	I_N	A	17	25	
Maximum speed at the rated torque	$n_{MAX,MN}$	rpm	63	110	
Rated power loss	$P_{V,N}$	W	4440	4440	
Limiting data					
Maximum torque	M_{MAX}	Nm	1390	1390	
Maximum current	I_{MAX}	A	31	47	
Electric power of the motor at M_{MAX}	$P_{EL,MAX}$	W	18200	22700	
Maximum mechanical speed	$n_{MAX,mech}$	rpm	630	630	
Maximum speed at the maximum torque	$n_{MAX,MMAX}$	rpm	33	64	
No-load speed	$n_{MAX,0}$	rpm	130	190	
Torque at n = rpm	M_0	Nm	941	941	
Current at M_0 and n = rpm	I_0	A	18	27	
Thermal standstill torque	M_0^*	Nm	666	666	
Thermal standstill current	I_0^*	A	12	18	
Physical constants					
Torque constant at 20 °C	$k_{T,20}$	Nm/A	54.1	36.1	
Voltage constant	k_E	V/(1000/min)	3274	2182	
Motor constant at 20 °C	$k_{M,20}$	$Nm/\sqrt{W}$	14.8	14.8	
Thermal time constant	t_{TH}	s	180	180	
Pole pair No.	p	-	42	42	
Cogging torque	M_{COG}	Nm	4.7	4.7	
Stator weight	m_S	kg	41.2	41.2	
Rotor weight	m_L	kg	14.6	14.6	
Rotor moment of inertia	J_L	10^{-2} kgm^2	48.6	48.6	
Winding phase resistance at 20 °C	$R_{STR,20}$	Ω	3.19	1.42	
Winding phase inductance	L_{PH}	mH	29.8	13.2	
Data, main motor cooler					
Maximum dissipated thermal power	$Q_{H,MAX}$	W	3690	3690	
Recommended minimum flow rate	$\dot{V}_{H\ MIN}$	l/min	6.5	6.5	
Temperature rise of the cooling medium	DT_H	K	8.2	8.2	
Pressure drop	Dp_H	bar	0.5	0.5	
Data, precision motor cooler					
Maximum dissipated thermal power	$Q_{P,MAX}$	W	749	749	
Recommended minimum flow rate	$\dot{V}_{P\ MIN}$	l/min	1.5	1.5	
Temperature rise of the cooling medium	DT_P	K	7	7	
Pressure drop	Dp_P	bar	0.5	0.5	

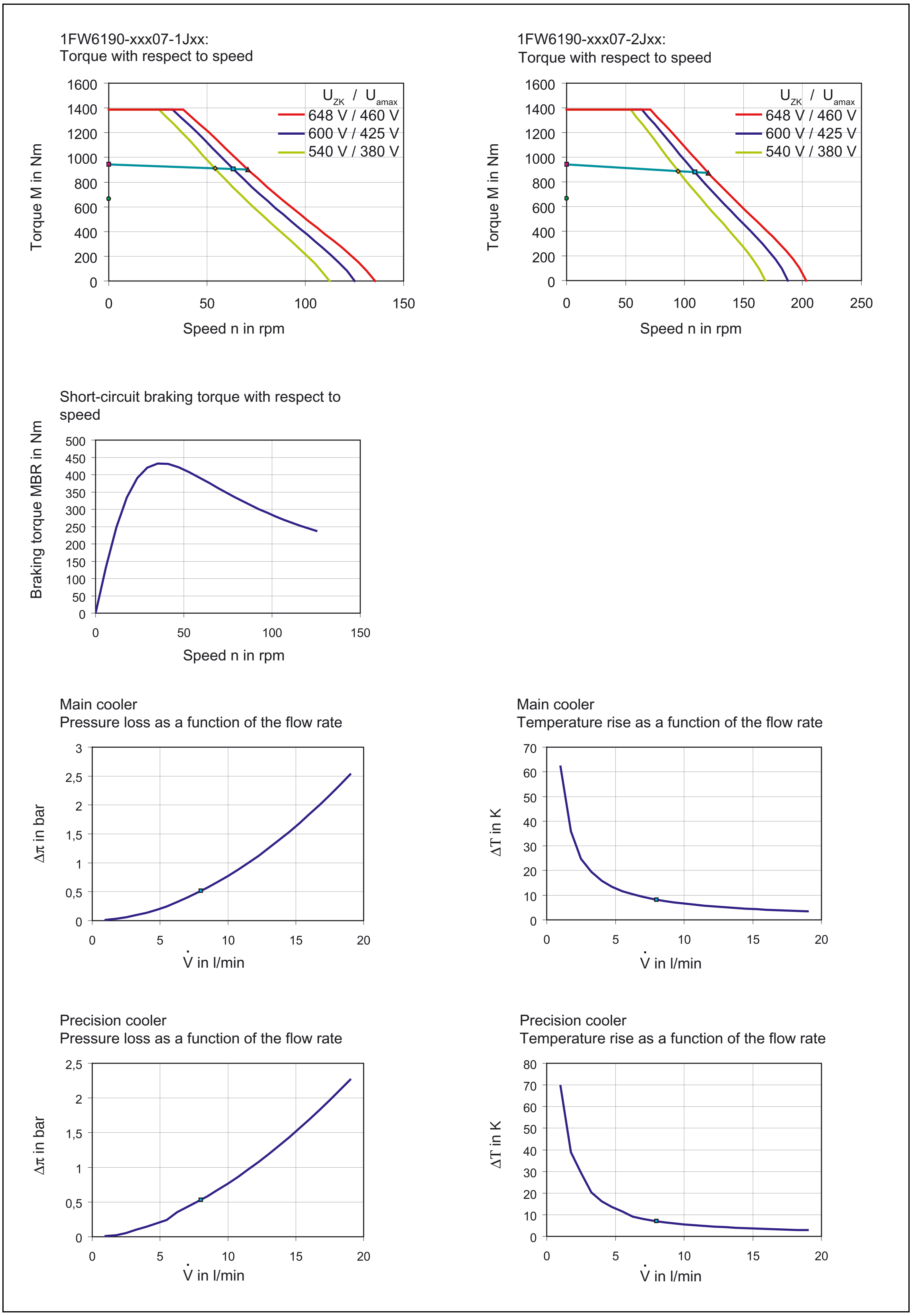


Figure 5-18: Characteristics for 1FW6190-xxx07-1Jxx, 1FW6190-xxx07-2Jxx

Table 5-16: 1FW6190-xxx10-1Jxx, 1FW6190-xxx10-2Jxx

1FW6190					
Technical Data	**Code**	**Units**	**-xxx10-1Jxx**	**-xxx10-2Jxx**	
Limitations					
DC link voltage	$V_{DC\ link}$	V	600	600	
Intake temperature of the water cooling	T_{INTAKE}	°C	35	35	
Rated temperature of the winding	T_N	°C	130	130	
Data at the rated operating point					
Rated torque	M_N	Nm	1310	1290	
Rated current	I_N	A	17	26	
Maximum speed at the rated torque	$n_{MAX,MN}$	rpm	38	70	
Rated power loss	$P_{V,N}$	W	5830	5830	
Limiting data					
Maximum torque	M_{MAX}	Nm	1980	1980	
Maximum current	I_{MAX}	A	31	47	
Electric power of the motor at M_{MAX}	$P_{EL,MAX}$	W	20700	25700	
Maximum mechanical speed	$n_{MAX,mech}$	rpm	630	630	
Maximum speed at the maximum torque	$n_{MAX,MMAX}$	rpm	14	39	
No-load speed	$n_{MAX,0}$	rpm	88	130	
Torque at n = rpm	M_0	Nm	1340	1340	
Current at M_0 and n = rpm	I_0	A	18	27	
Thermal standstill torque	M_0^*	Nm	951	951	
Thermal standstill current	I_0^*	A	12	18	
Physical constants					
Torque constant at 20 °C	$k_{T,20}$	Nm/A	77.3	51.6	
Voltage constant	k_E	V/(1000/min)	4676	3118	
Motor constant at 20 °C	$k_{M,20}$	$Nm/\sqrt{W}$	18.5	18.5	
Thermal time constant	t_{TH}	s	180	180	
Pole pair No.	p	-	42	42	
Cogging torque	M_{COG}	Nm	6.7	6.7	
Stator weight	m_S	kg	55.5	55.5	
Rotor weight	m_L	kg	20.3	20.3	
Rotor moment of inertia	J_L	10^{-2} kgm^2	67.8	67.8	
Winding phase resistance at 20 °C	$R_{STR,20}$	Ω	4.19	1.86	
Winding phase inductance	L_{PH}	mH	42.2	18.8	
Data, main motor cooler					
Maximum dissipated thermal power	$Q_{H,MAX}$	W	5090	5090	
Recommended minimum flow rate	$\dot{V}_{H\ MIN}$	l/min	7.3	7.3	
Temperature rise of the cooling medium	DT_H	K	10.1	10.1	
Pressure drop	Dp_H	bar	0.6	0.6	
Data, precision motor cooler					
Maximum dissipated thermal power	$Q_{P,MAX}$	W	733	733	
Recommended minimum flow rate	$\dot{V}_{P\ MIN}$	l/min	1.7	1.7	
Temperature rise of the cooling medium	DT_P	K	6.1	6.1	
Pressure drop	Dp_P	bar	0.6	0.6	

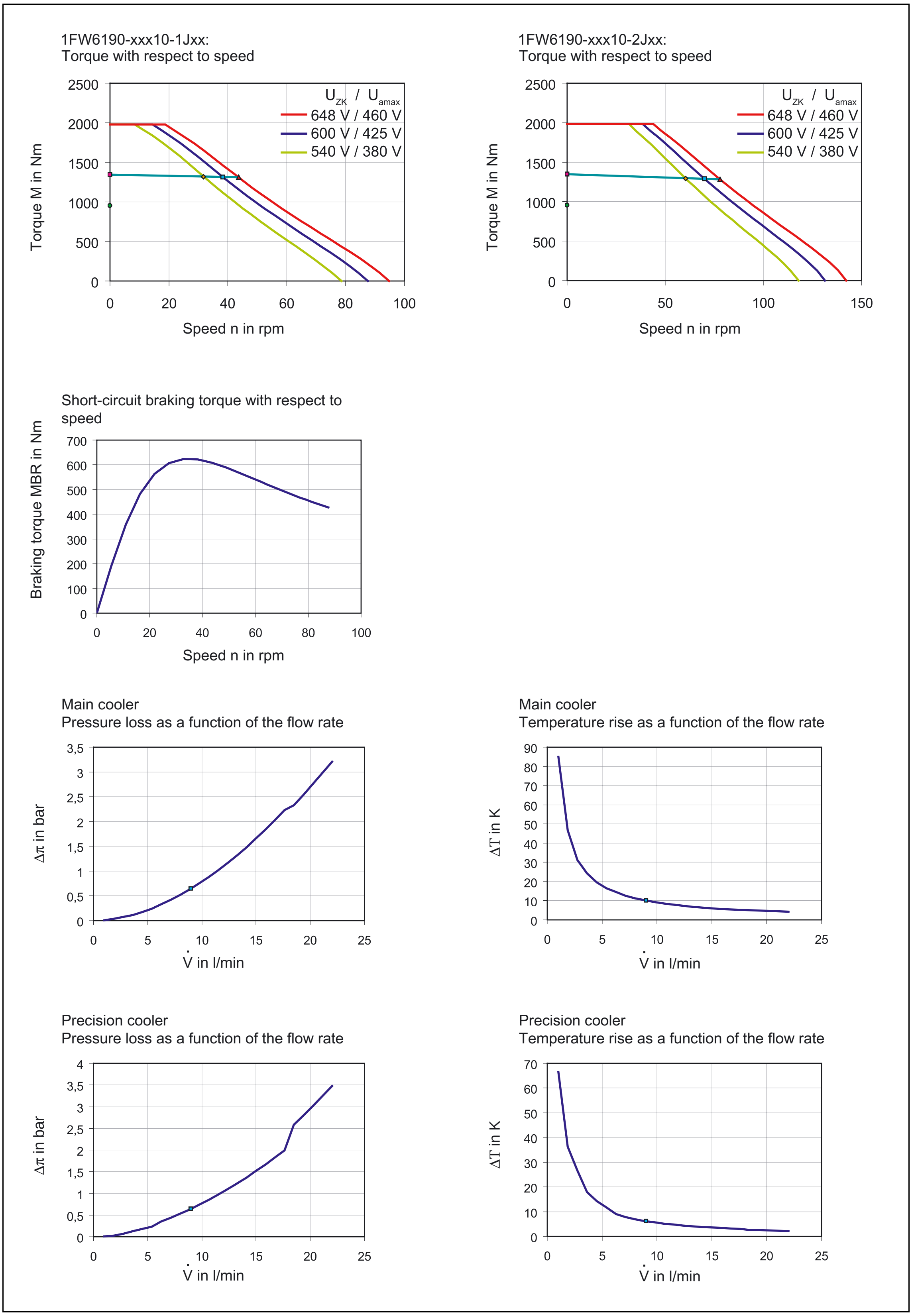


Figure 5-19: Characteristics for 1FW6190-xxx10-1Jxx, 1FW6190-xxx10-2Jxx

Table 5-17: 1FW6190-xxx15-2Jxx, 1FW6190-xxx15-5Gxx

1FW6190					
Technical Data	**Code**	**Units**	**-xxx15-2Jxx**	**-xxx15-5Gxx**	
Limitations					
DC link voltage	$V_{DC\ link}$	V	600	600	
Intake temperature of the water cooling	T_{INTAKE}	°C	35	35	
Rated temperature of the winding	T_N	°C	130	130	
Data at the rated operating point					
Rated torque	M_N	Nm	1970	1890	
Rated current	I_N	A	26	50	
Maximum speed at the rated torque	$n_{MAX,MN}$	rpm	40	100	
Rated power loss	$P_{V,N}$	W	8140	8140	
Limiting data					
Maximum torque	M_{MAX}	Nm	2970	2970	
Maximum current	I_{MAX}	A	47	95	
Electric power of the motor at M_{MAX}	$P_{EL,MAX}$	W	30100	44100	
Maximum mechanical speed	$n_{MAX,mech}$	rpm	630	630	
Maximum speed at the maximum torque	$n_{MAX,MMAX}$	rpm	17	62	
No-load speed	$n_{MAX,0}$	rpm	88	180	
Torque at n = rpm	M_0	Nm	2020	2020	
Current at M_0 and n = rpm	I_0	A	27	54	
Thermal standstill torque	M_0^*	Nm	1430	1430	
Thermal standstill current	I_0^*	A	18	37	
Physical constants					
Torque constant at 20 °C	$k_{T,20}$	Nm/A	77.3	38.7	
Voltage constant	k_E	V/(1000/min)	4676	2338	
Motor constant at 20 °C	$k_{M,20}$	$Nm/\sqrt{W}$	23.4	23.4	
Thermal time constant	t_{TH}	s	180	180	
Pole pair No.	p	-	42	42	
Cogging torque	M_{COG}	Nm	10	10	
Stator weight	m_S	kg	77.8	77.8	
Rotor weight	m_L	kg	30	30	
Rotor moment of inertia	J_L	10^{-2} kgm^2	99.8	99.8	
Winding phase resistance at 20 °C	$R_{STR,\ 20}$	Ω	2.6	0.651	
Winding phase inductance	L_{PH}	mH	28	7	
Data, main motor cooler					
Maximum dissipated thermal power	$Q_{H,MAX}$	W	7420	7420	
Recommended minimum flow rate	$\dot{V}_{H\ MIN}$	l/min	9.7	9.7	
Temperature rise of the cooling medium	DT_H	K	10.9	10.9	
Pressure drop	Dp_H	bar	1.1	1.1	
Data, precision motor cooler					
Maximum dissipated thermal power	$Q_{P,MAX}$	W	721	721	
Recommended minimum flow rate	$\dot{V}_{P\ MIN}$	l/min	2.3	2.3	
Temperature rise of the cooling medium	DT_P	K	4.6	4.6	
Pressure drop	Dp_P	bar	1	1	

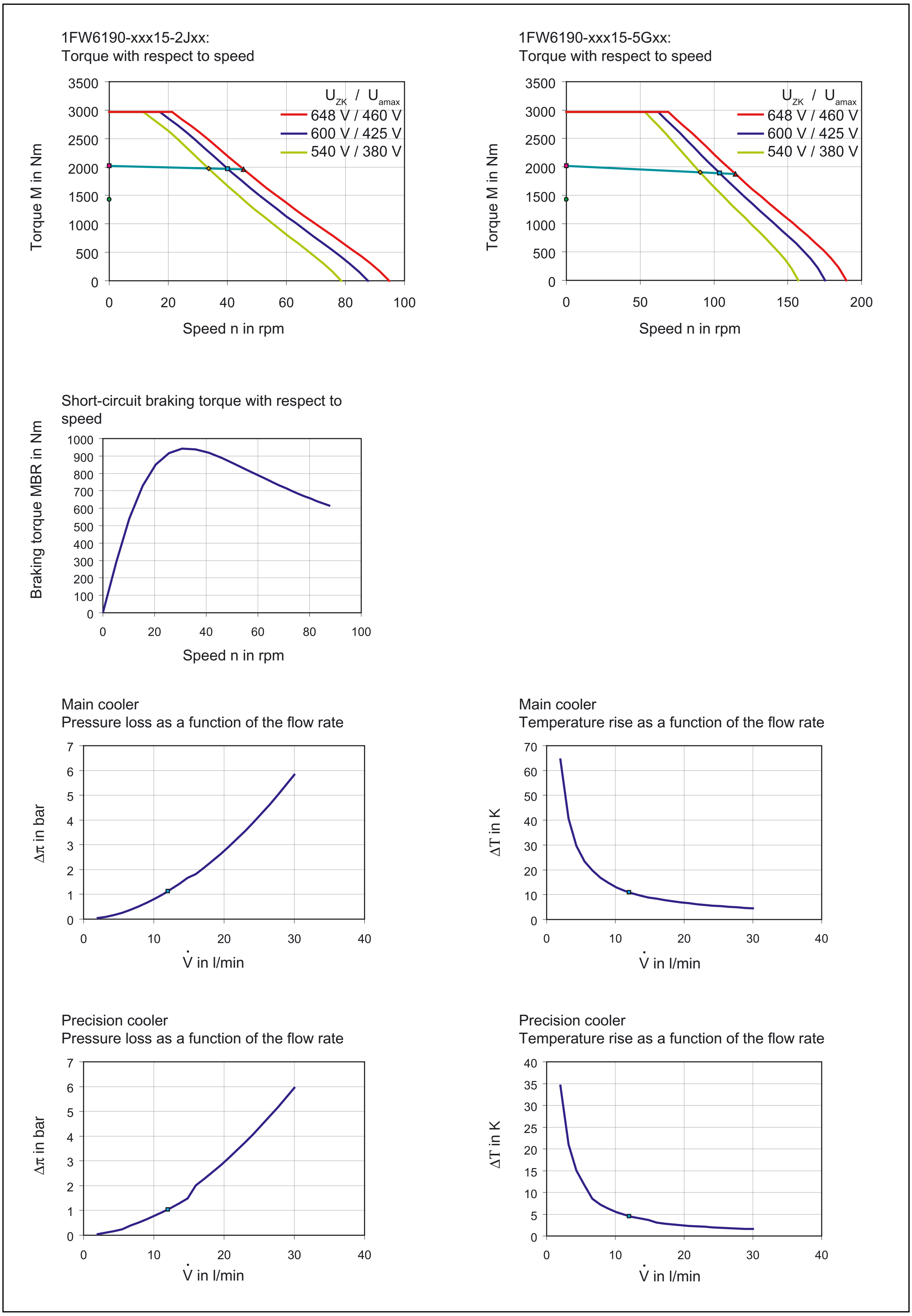


Figure 5-20: Characteristics for 1FW6190-xxx15-2Jxx, 1FW6190-xxx15-5Gxx

5.3.5 1FW6230-xxxxx-xxxx

Table 5-18: 1FW6230-xxx05-1Jxx, 1FW6230-xxx05-2Jxx

1FW6230					
Technical Data	**Code**	**Units**	**-xxx05-1Jxx**	**-xxx05-2Jxx**	
Limitations					
DC link voltage	$V_{DC\ link}$	V	600	600	
Intake temperature of the water cooling	T_{INTAKE}	°C	35	35	
Rated temperature of the winding	T_N	°C	130	130	
Data at the rated operating point					
Rated torque	M_N	Nm	799	774	
Rated current	I_N	A	15	22	
Maximum speed at the rated torque	$n_{MAX,MN}$	rpm	69	110	
Rated power loss	$P_{V,N}$	W	3540	3650	
Limiting data					
Maximum torque	M_{MAX}	Nm	1320	1320	
Maximum current	I_{MAX}	A	31	45	
Electric power of the motor at M_{MAX}	$P_{EL,MAX}$	W	17300	21000	
Maximum mechanical speed	$n_{MAX,mech}$	rpm	580	580	
Maximum speed at the maximum torque	$n_{MAX,MMAX}$	rpm	34	59	
No-load speed	$n_{MAX,0}$	rpm	130	190	
Torque at n = rpm	M_0	Nm	841	841	
Current at M_0 and n = rpm	I_0	A	16	24	
Thermal standstill torque	M_0^*	Nm	594	594	
Thermal standstill current	I_0^*	A	11	16	
Physical constants					
Torque constant at 20 °C	$k_{T,20}$	Nm/A	52.7	36.9	
Voltage constant	k_E	V/(1000/min)	3188	2231	
Motor constant at 20 °C	$k_{M,20}$	$Nm/\sqrt{W}$	15	14.8	
Thermal time constant	t_{TH}	s	180	180	
Pole pair No.	p	-	49	49	
Cogging torque	M_{COG}	Nm	4.2	4.2	
Stator weight	m_S	kg	31.9	31.9	
Rotor weight	m_L	kg	12.9	12.9	
Rotor moment of inertia	J_L	10^{-2} kgm^2	62.2	62.2	
Winding phase resistance at 20 °C	$R_{STR,20}$	Ω	2.95	1.49	
Winding phase inductance	L_{PH}	mH	26.9	13.2	
Data, main motor cooler					
Maximum dissipated thermal power	$Q_{H,MAX}$	W	2740	2820	
Recommended minimum flow rate	$\dot{V}_{H\ MIN}$	l/min	5.3	5.3	
Temperature rise of the cooling medium	DT_H	K	7.4	7.7	
Pressure drop	Dp_H	bar	0.3	0.3	
Data, precision motor cooler					
Maximum dissipated thermal power	$Q_{P,MAX}$	W	805	829	
Recommended minimum flow rate	$\dot{V}_{P\ MIN}$	l/min	1.1	1.1	
Temperature rise of the cooling medium	DT_P	K	10.4	10.7	
Pressure drop	Dp_P	bar	0.3	0.3	

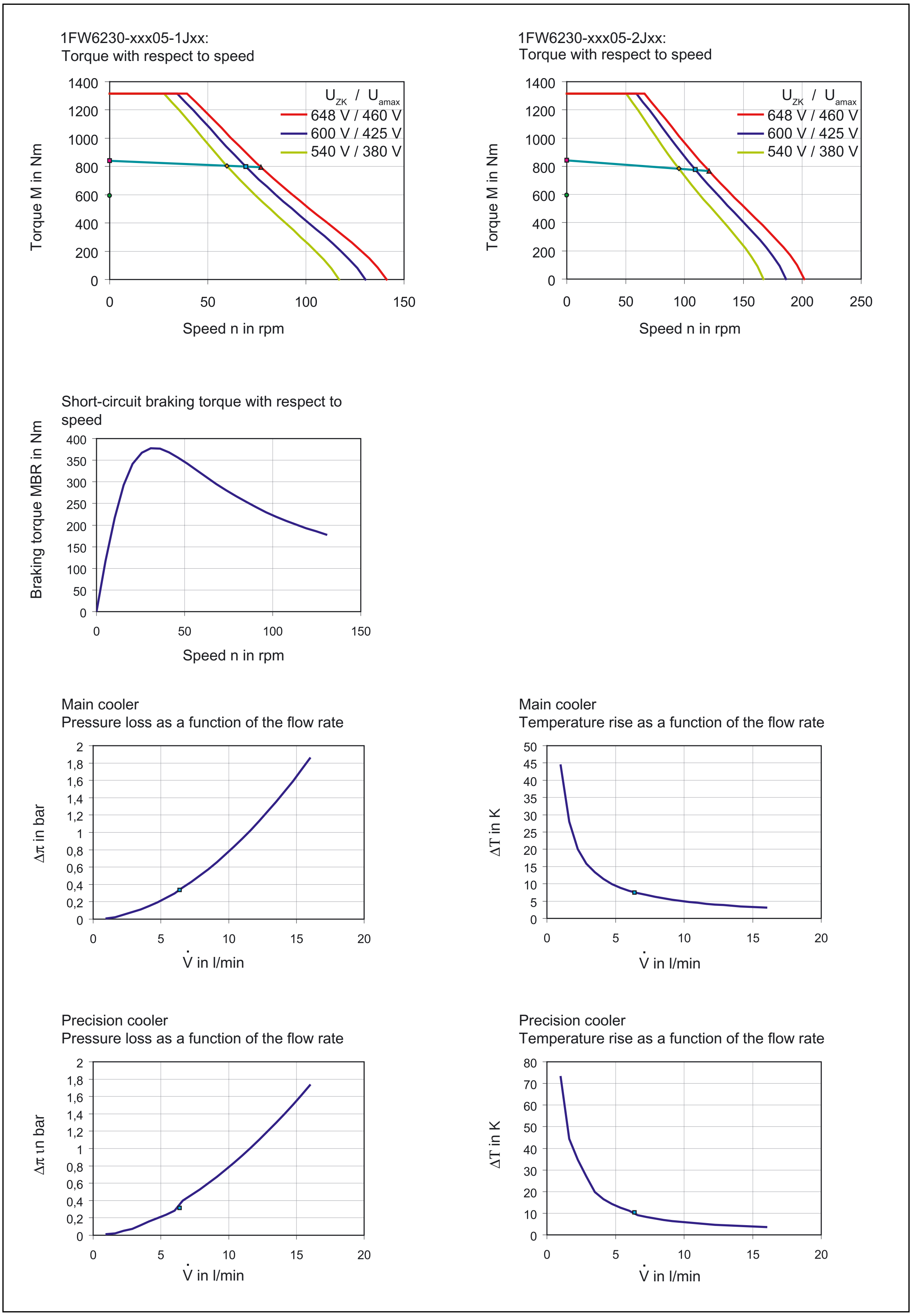


Figure 5-21: Characteristics for 1FW6230-xxx05-1Jxx, 1FW6230-xxx05-2Jxx

Table 5-19: 1FW6230-xxx07-1Jxx, 1FW6230-xxx07-2Jxx

1FW6230					
Technical Data	**Code**	**Units**	**-xxx07-1Jxx**	**-xxx07-2Jxx**	
Limitations					
DC link voltage	$V_{DC\ link}$	V	600	600	
Intake temperature of the water cooling	T_{INTAKE}	°C	35	35	
Rated temperature of the winding	T_N	°C	130	130	
Data at the rated operating point					
Rated torque	M_N	Nm	1140	1120	
Rated current	I_N	A	16	22	
Maximum speed at the rated torque	$n_{MAX,MN}$	rpm	45	73	
Rated power loss	$P_{V,N}$	W	4470	4610	
Limiting data					
Maximum torque	M_{MAX}	Nm	1840	1840	
Maximum current	I_{MAX}	A	31	45	
Electric power of the motor at M_{MAX}	$P_{EL,MAX}$	W	19400	23600	
Maximum mechanical speed	$n_{MAX,mech}$	rpm	580	580	
Maximum speed at the maximum torque	$n_{MAX,MMAX}$	rpm	19	38	
No-load speed	$n_{MAX,0}$	rpm	93	130	
Torque at n = rpm	M_0	Nm	1180	1180	
Current at M_0 and n = rpm	I_0	A	16	24	
Thermal standstill torque	M_0^*	Nm	832	832	
Thermal standstill current	I_0^*	A	11	16	
Physical constants					
Torque constant at 20 °C	$k_{T,20}$	Nm/A	73.8	51.7	
Voltage constant	k_E	V/(1000/min)	4463	3124	
Motor constant at 20 °C	$k_{M,20}$	$Nm/\sqrt{W}$	18.7	18.4	
Thermal time constant	t_{TH}	s	180	180	
Pole pair No.	p	-	49	49	
Cogging torque	M_{COG}	Nm	5.9	5.9	
Stator weight	m_S	kg	41.4	41.4	
Rotor weight	m_L	kg	17.4	17.4	
Rotor moment of inertia	J_L	10^{-2} kgm^2	84.3	84.3	
Winding phase resistance at 20 °C	$R_{STR,20}$	Ω	3.73	1.88	
Winding phase inductance	L_{PH}	mH	37.3	18.3	
Data, main motor cooler					
Maximum dissipated thermal power	$Q_{H,MAX}$	W	3710	3820	
Recommended minimum flow rate	$\dot{V}_{H\ MIN}$	l/min	6.7	6.7	
Temperature rise of the cooling medium	DT_H	K	7.9	8.2	
Pressure drop	Dp_H	bar	0.6	0.6	
Data, precision motor cooler					
Maximum dissipated thermal power	$Q_{P,MAX}$	W	768	791	
Recommended minimum flow rate	$\dot{V}_{P\ MIN}$	l/min	1.6	1.6	
Temperature rise of the cooling medium	DT_P	K	7	7.2	
Pressure drop	Dp_P	bar	0.6	0.6	

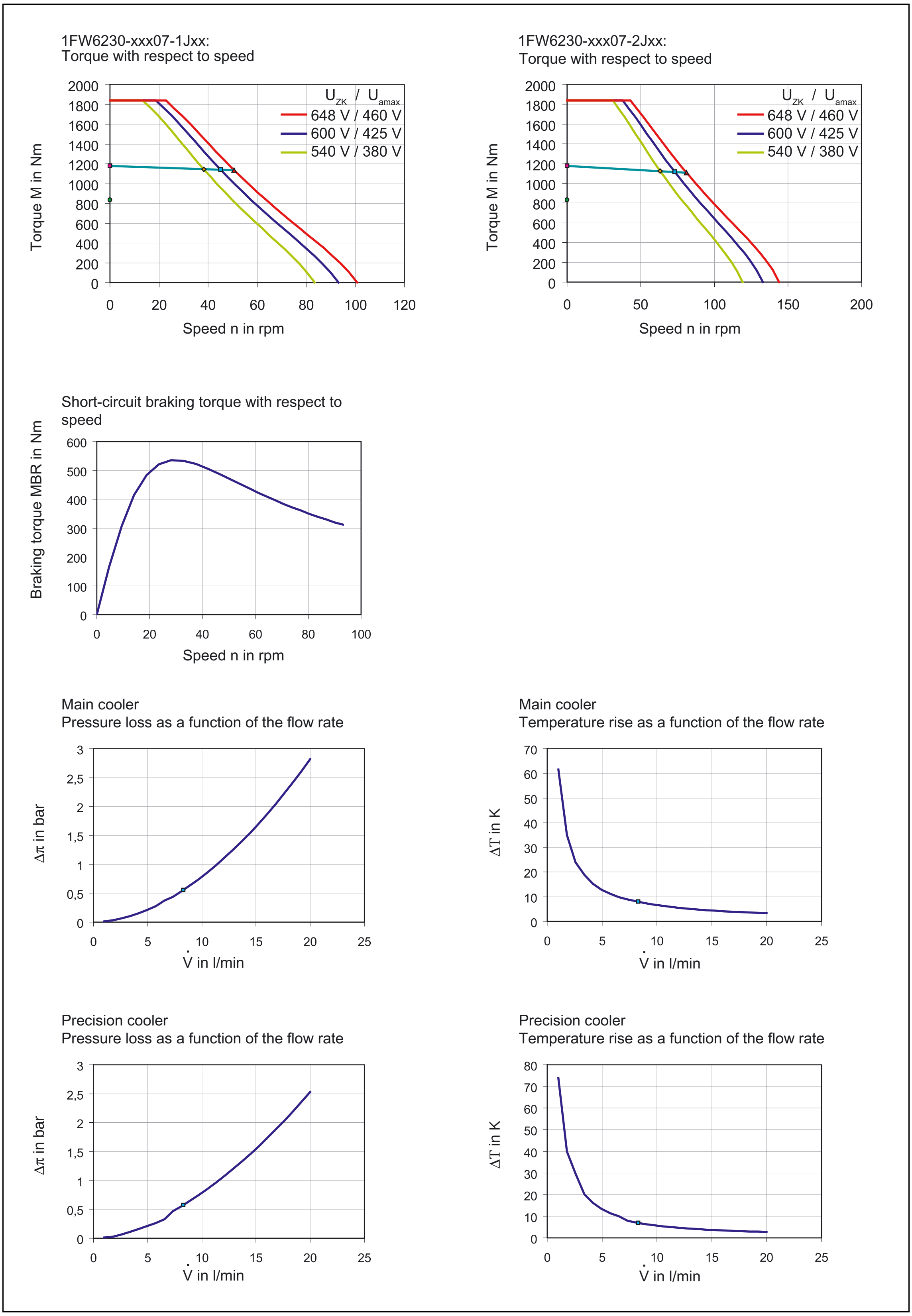


Figure 5-22: Characteristics for 1FW6230-xxx07-1Jxx, 1FW6230-xxx07-2Jxx

Table 5-20: 1FW6230-xxx10-2Jxx, 1FW6230-xxx10-5Gxx

1FW6230					
Technical Data	**Code**	**Units**	**-xxx10-2Jxx**	**-xxx10-5Gxx**	
Limitations					
DC link voltage	$V_{DC\ link}$	V	600	600	
Intake temperature of the water cooling	T_{INTAKE}	°C	35	35	
Rated temperature of the winding	T_N	°C	130	130	
Data at the rated operating point					
Rated torque	M_N	Nm	1630	1520	
Rated current	I_N	A	23	48	
Maximum speed at the rated torque	$n_{MAX,MN}$	rpm	46	130	
Rated power loss	$P_{V,N}$	W	6050	6090	
Limiting data					
Maximum torque	M_{MAX}	Nm	2630	2630	
Maximum current	I_{MAX}	A	45	100	
Electric power of the motor at M_{MAX}	$P_{EL,MAX}$	W	27100	42000	
Maximum mechanical speed	$n_{MAX,mech}$	rpm	580	580	
Maximum speed at the maximum torque	$n_{MAX,MMAX}$	rpm	21	74	
No-load speed	$n_{MAX,0}$	rpm	93	210	
Torque at n = rpm	M_0	Nm	1680	1680	
Current at M_0 and n = rpm	I_0	A	24	54	
Thermal standstill torque	M_0^*	Nm	1190	1190	
Thermal standstill current	I_0^*	A	16	37	
Physical constants					
Torque constant at 20 °C	$k_{T,20}$	Nm/A	73.8	32.7	
Voltage constant	k_E	V/(1000/min)	4463	1976	
Motor constant at 20 °C	$k_{M,20}$	$Nm/\sqrt{W}$	23	22.9	
Thermal time constant	t_{TH}	s	180	180	
Pole pair No.	p	-	49	49	
Cogging torque	M_{COG}	Nm	8.4	8.4	
Stator weight	m_S	kg	57.5	57.5	
Rotor weight	m_L	kg	24.3	24.3	
Rotor moment of inertia	J_L	10^{-2} kgm^2	118	118	
Winding phase resistance at 20 °C	$R_{STR,\ 20}$	Ω	2.47	0.488	
Winding phase inductance	L_{PH}	mH	25.9	5.1	
Data, main motor cooler					
Maximum dissipated thermal power	$Q_{H,MAX}$	W	5290	5320	
Recommended minimum flow rate	$\dot{V}_{H\ MIN}$	l/min	8.8	8.8	
Temperature rise of the cooling medium	DT_H	K	8.6	8.7	
Pressure drop	Dp_H	bar	0.9	0.9	
Data, precision motor cooler					
Maximum dissipated thermal power	$Q_{P,MAX}$	W	762	767	
Recommended minimum flow rate	$\dot{V}_{P\ MIN}$	l/min	2.1	2.1	
Temperature rise of the cooling medium	DT_P	K	5.3	5.4	
Pressure drop	Dp_P	bar	0.9	0.9	

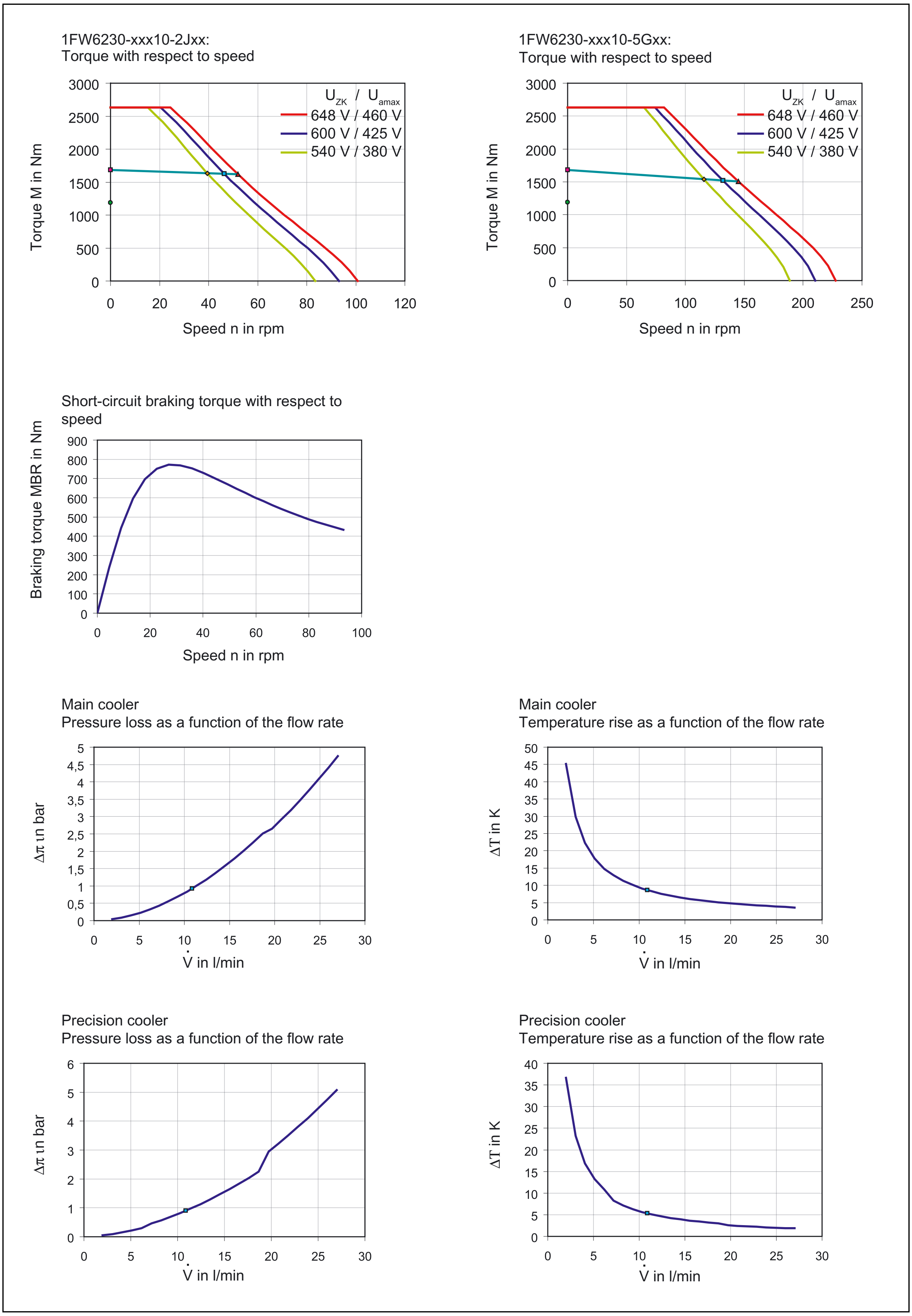


Figure 5-23: Characteristics for 1FW6230-xxx10-2Jxx, 1FW6230-xxx10-5Gxx

Table 5-21: 1FW6230-xxx15-4Cxx, 1FW6230-xxx15-5Gxx

1FW6230					
Technical Data	**Code**	**Units**	**-xxx15-4Cxx**	**-xxx15-5Gxx**	
Limitations					
DC link voltage	$V_{DC\ link}$	V	600	600	
Intake temperature of the water cooling	T_{INTAKE}	°C	35	35	
Rated temperature of the winding	T_N	°C	130	130	
Data at the rated operating point					
Rated torque	M_N	Nm	2440	2380	
Rated current	I_N	A	32	49	
Maximum speed at the rated torque	$n_{MAX,MN}$	rpm	43	80	
Rated power loss	$P_{V,N}$	W	8510	8290	
Limiting data					
Maximum torque	M_{MAX}	Nm	3950	3950	
Maximum current	I_{MAX}	A	63	100	
Electric power of the motor at M_{MAX}	$P_{EL,MAX}$	W	38000	47400	
Maximum mechanical speed	$n_{MAX,mech}$	rpm	580	580	
Maximum speed at the maximum torque	$n_{MAX,MMAX}$	rpm	19	44	
No-load speed	$n_{MAX,0}$	rpm	87	140	
Torque at n = rpm	M_0	Nm	2520	2520	
Current at M_0 and n = rpm	I_0	A	33	53	
Thermal standstill torque	M_0^*	Nm	1780	1780	
Thermal standstill current	I_0^*	A	23	36	
Physical constants					
Torque constant at 20 °C	$k_{T,20}$	Nm/A	79.1	50.2	
Voltage constant	k_E	V/(1000/min)	4782	3033	
Motor constant at 20 °C	$k_{M,20}$	$Nm/\sqrt{W}$	29.1	29.4	
Thermal time constant	t_{TH}	s	180	180	
Pole pair No.	p	-	49	49	
Cogging torque	M_{COG}	Nm	13	13	
Stator weight	m_S	kg	82.1	82.1	
Rotor weight	m_L	kg	35.7	35.7	
Rotor moment of inertia	J_L	10^{-2} kgm^2	173	173	
Winding phase resistance at 20 °C	$R_{STR,20}$	Ω	1.77	0.695	
Winding phase inductance	L_{PH}	mH	19.7	7.9	
Data, main motor cooler					
Maximum dissipated thermal power	$Q_{H,MAX}$	W	7760	7560	
Recommended minimum flow rate	$\dot{V}_{H\ MIN}$	l/min	12.6	12.6	
Temperature rise of the cooling medium	DT_H	K	8.9	8.6	
Pressure drop	Dp_H	bar	1.8	1.8	
Data, precision motor cooler					
Maximum dissipated thermal power	$Q_{P,MAX}$	W	752	733	
Recommended minimum flow rate	$\dot{V}_{P\ MIN}$	l/min	2.9	2.9	
Temperature rise of the cooling medium	DT_P	K	3.7	3.6	
Pressure drop	Dp_P	bar	1.6	1.6	

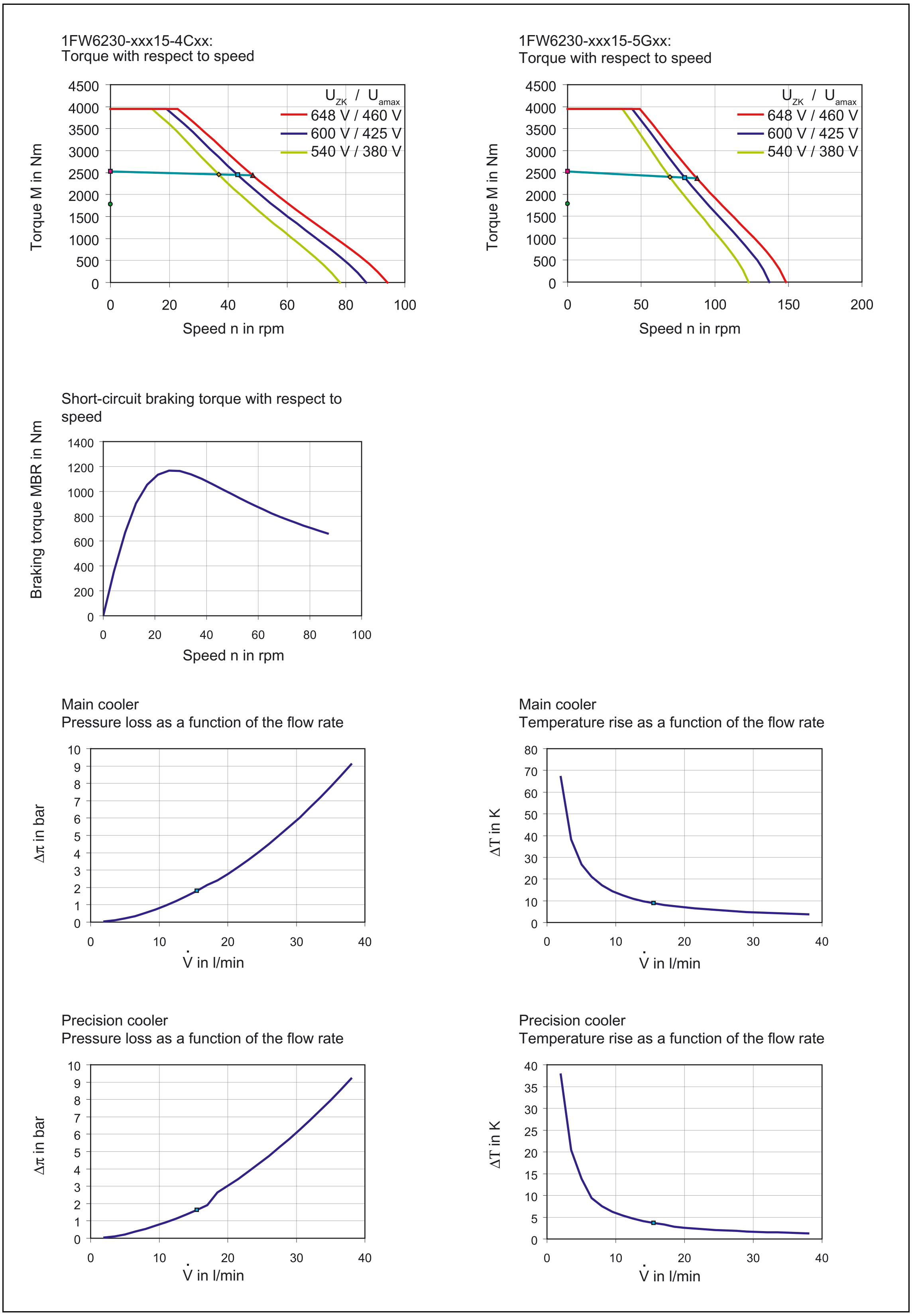


Figure 5-24: Characteristics for 1FW6230-xxx15-4Cxx, 1FW6230-xxx15-5Gxx

5.3.6 1FW6290-xxxxx-xxxx

Table 5-22: 1FW6290-xxx15-7Axx

1FW6290					
Technical Data	**Code**	**Units**	**-xxx15-7Axx**		
Limitations					
DC link voltage	$V_{DC\ link}$	V	600		
Intake temperature of the water cooling	T_{INTAKE}	°C	35		
Rated temperature of the winding	T_N	°C	130		
Data at the rated operating point					
Rated torque	M_N	Nm	4590		
Rated current	I_N	A	61		
Maximum speed at the rated torque	$n_{MAX,MN}$	rpm	53		
Rated power loss	$P_{V,N}$	W	9080		
Limiting data					
Maximum torque	M_{MAX}	Nm	8570		
Maximum current	I_{MAX}	A	130		
Electric power of the motor at M_{MAX}	$P_{EL,MAX}$	W	65200		
Maximum mechanical speed	$n_{MAX,mech}$	rpm	470		
Maximum speed at the maximum torque	$n_{MAX,MMAX}$	rpm	28		
No-load speed	$n_{MAX,0}$	rpm	85		
Torque at n = rpm	M_0	Nm	4760		
Current at M_0 and n = rpm	I_0	A	64		
Thermal standstill torque	M_0^*	Nm	3370		
Thermal standstill current	I_0^*	A	44		
Physical constants					
Torque constant at 20 °C	$k_{T,20}$	Nm/A	75		
Voltage constant	k_E	V/(1000/min)	4533		
Motor constant at 20 °C	$k_{M,20}$	$Nm/\sqrt{W}$	50.6		
Thermal time constant	t_{TH}	s	180		
Pole pair No.	p	-	42		
Cogging torque	M_{COG}	Nm	24		
Stator weight	m_S	kg	155.6		
Rotor weight	m_L	kg	59		
Rotor moment of inertia	J_L	10^{-2} kgm^2	440		
Winding phase resistance at 20 °C	$R_{STR,20}$	Ω	0.526		
Winding phase inductance	L_{PH}	mH	10.4		
Data, main motor cooler					
Maximum dissipated thermal power	$Q_{H,MAX}$	W	8010		
Recommended minimum flow rate	$\dot{V}_{H\ MIN}$	l/min	13.2		
Temperature rise of the cooling medium	DT_H	K	8.7		
Pressure drop	Dp_H	bar	1.4		
Data, precision motor cooler					
Maximum dissipated thermal power	$Q_{P,MAX}$	W	1070		
Recommended minimum flow rate	$\dot{V}_{P\ MIN}$	l/min	4.8		
Temperature rise of the cooling medium	DT_P	K	3.2		
Pressure drop	Dp_P	bar	1.4		

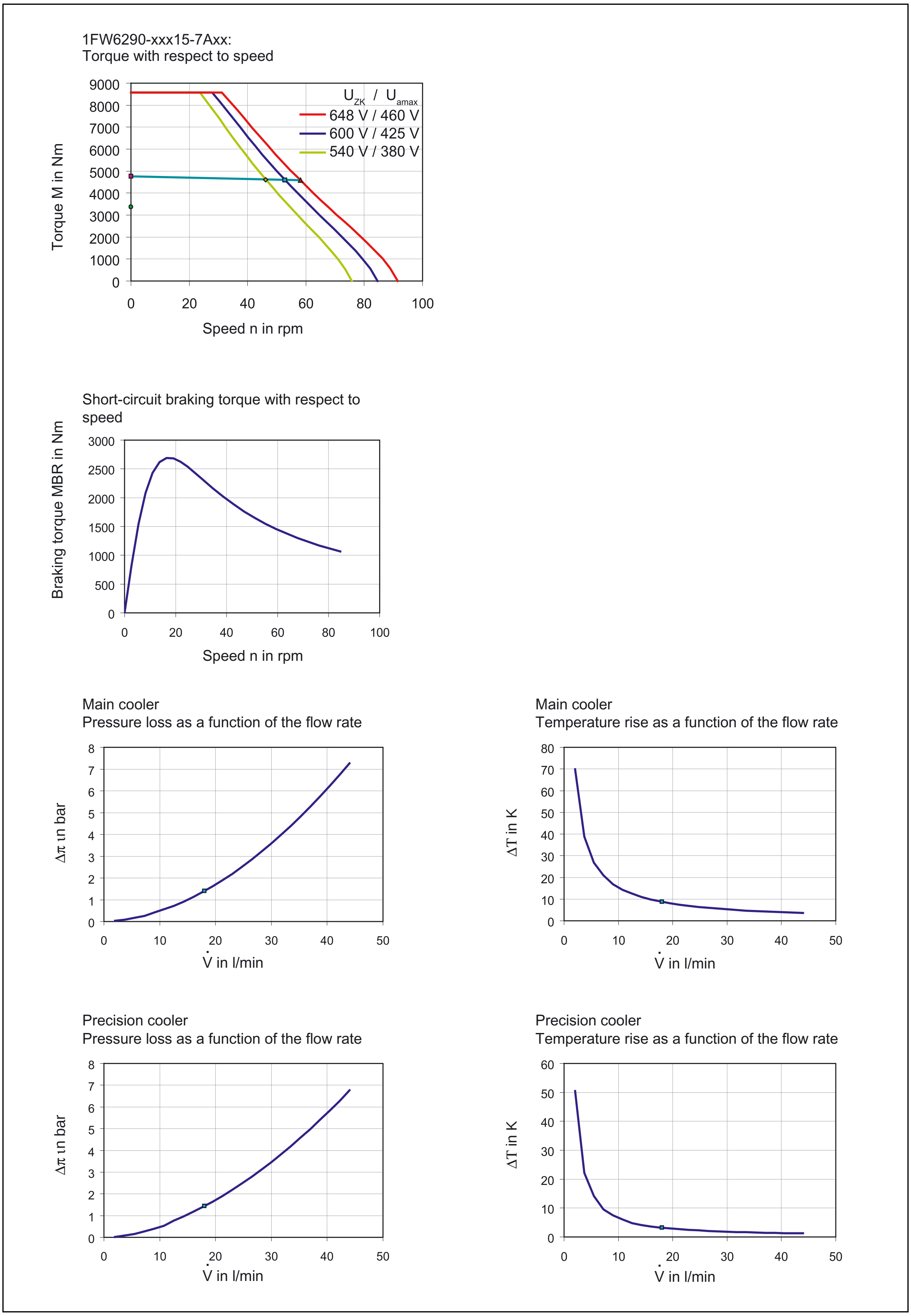


Figure 5-25: Characteristics for 1FW6290-xxx15-7Axx

Space for your notes

6 Installation Drawings

6

6.1 Explanation of the installation situation

For the mechanical design it is important that you observe the following dimensions: Also refer to Chapter "Dimension drawings / installation drawings".

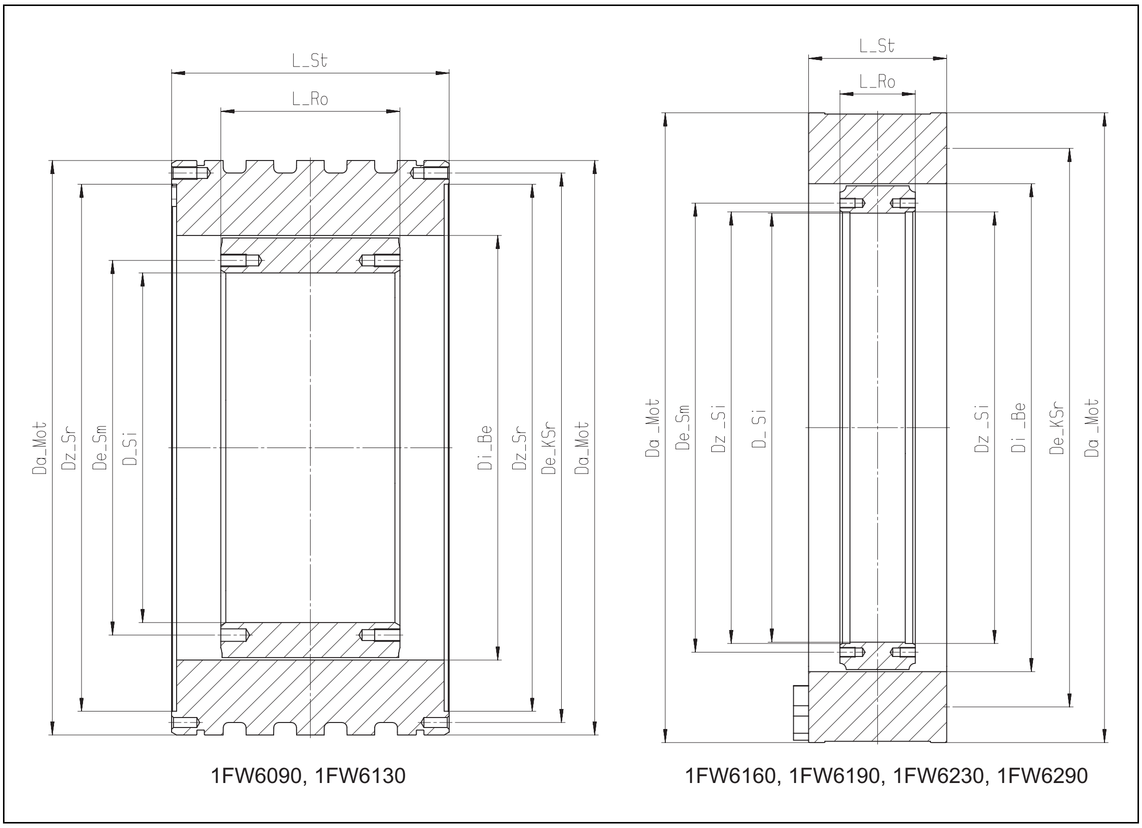


Figure 6-1: Geometrical data of the 1FW6 built-in torque motors

Explanation of the designations in Figure 6-1:

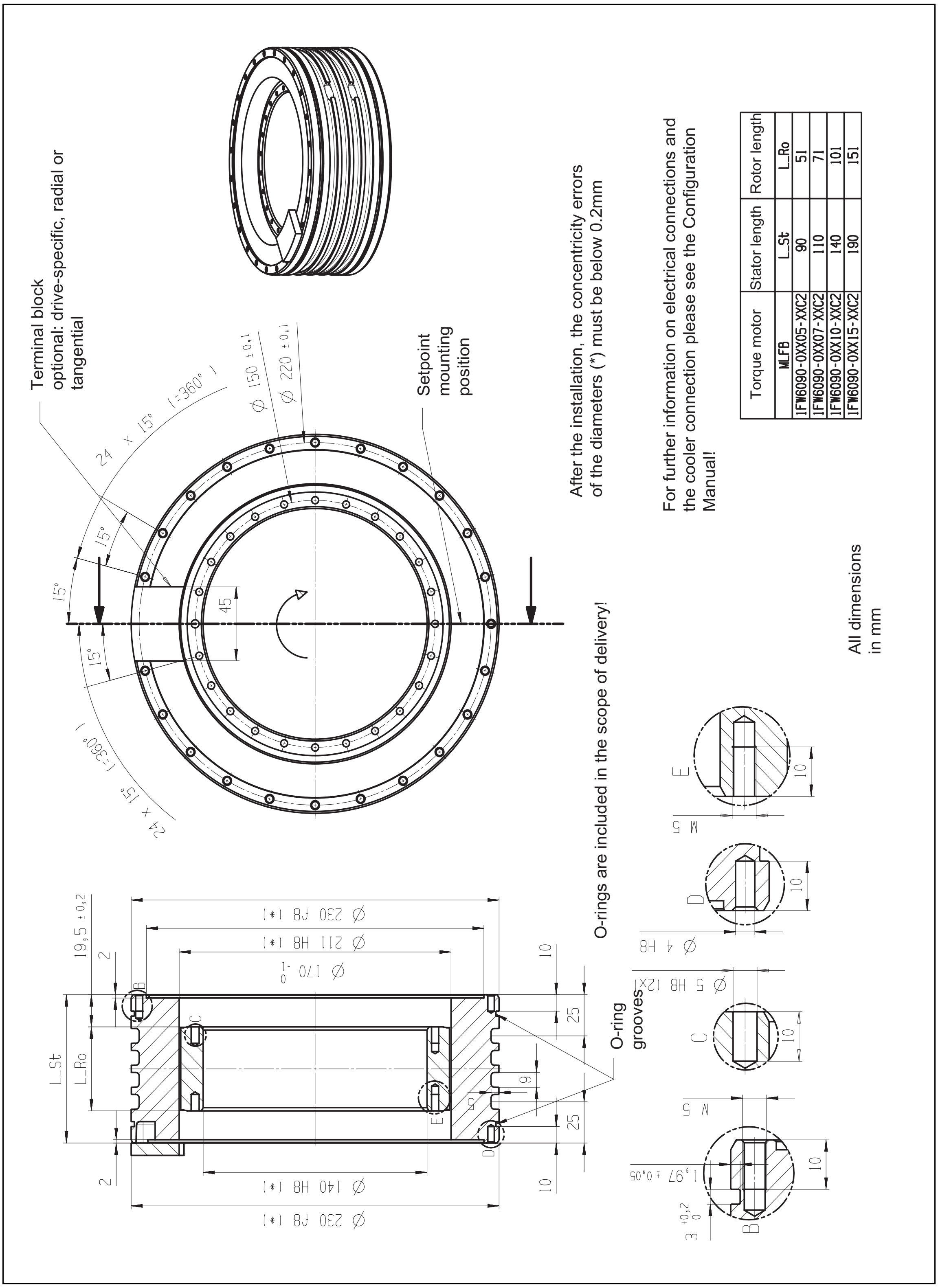
L_St	Length, stator
L_Ro	Length, rotor
Dz_Sr	Diameter of the centering face at the stator
Da_Mot	Outer motor diameter
De_Sm	Diameter, circle of holes of the retaining bolts at the rotor
De_KSr	Diameter, circle of holes of the retaining bolts at the stator
Di_Be	Inner stator diameter
Dz_Si	Diameter of the centering face at the rotor
D_Si	Inner rotor diameter

Note

Siemens AG reserves the right to change the motor dimensions, as part of design improvements, without prior notification. The dimension drawings provided in this documentation can go out-of-date.

Up-to-date dimension drawings can be requested at no charge.

6.2 Dimension drawings / installation drawings



Torque motor MLFB	Stator length L_St	Rotor length L_Ro
1FW6090-0XX05-XXC2	90	51
1FW6090-0XX07-XXC2	110	71
1FW6090-0XX10-XXC2	140	101
1FW6090-0XX15-XXC2	190	151

Figure 6-2: 1FW6090-...

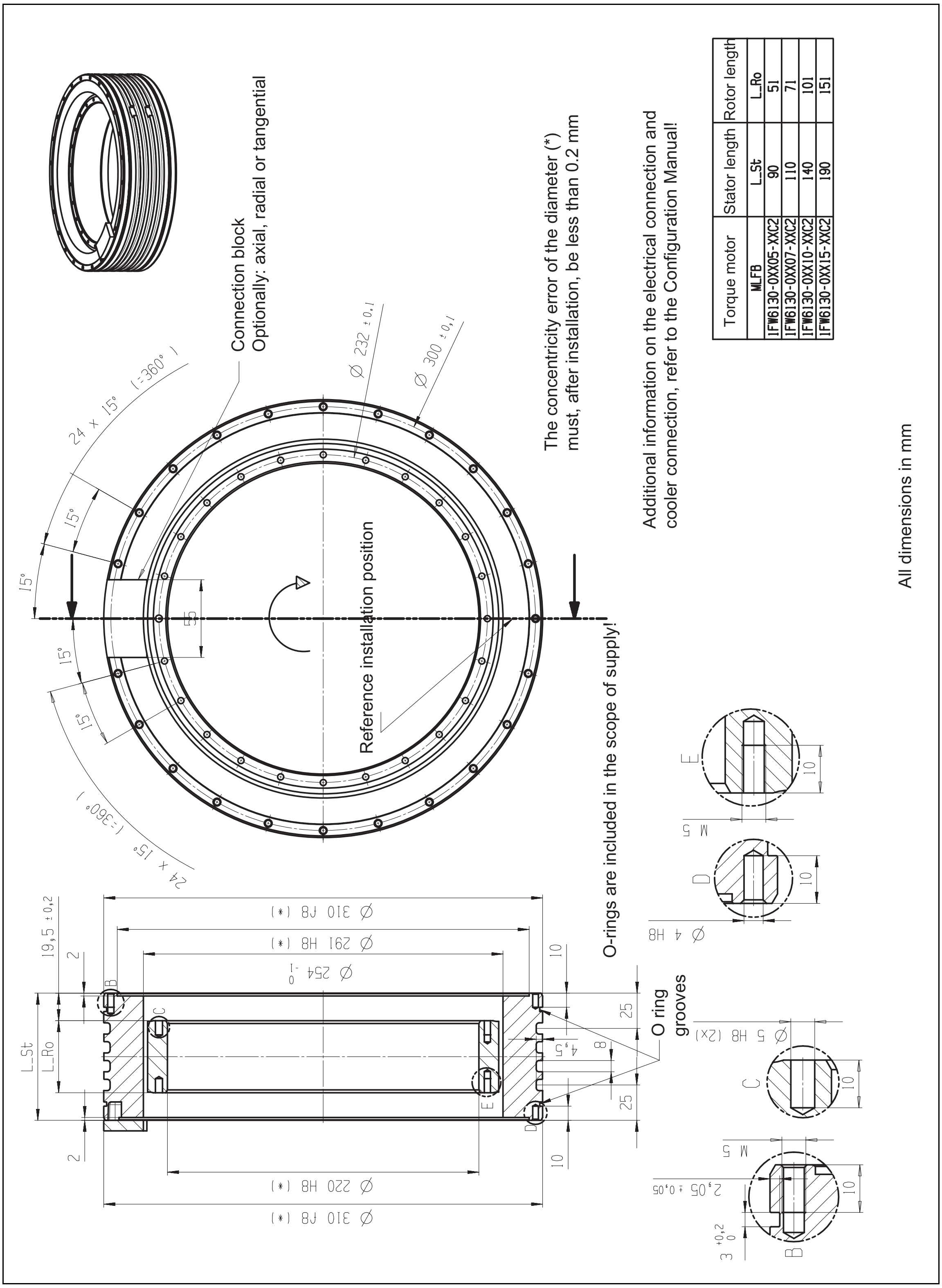
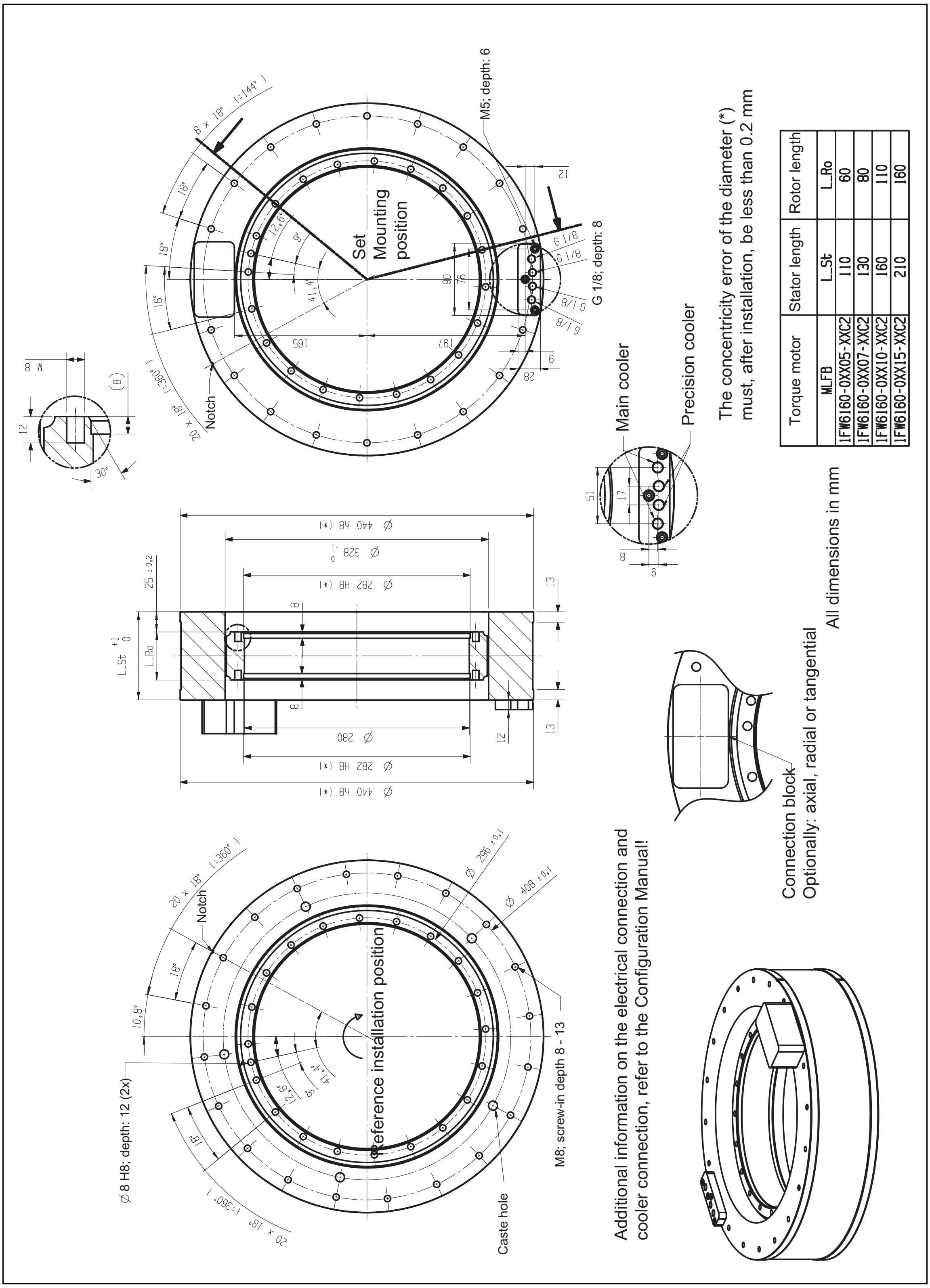
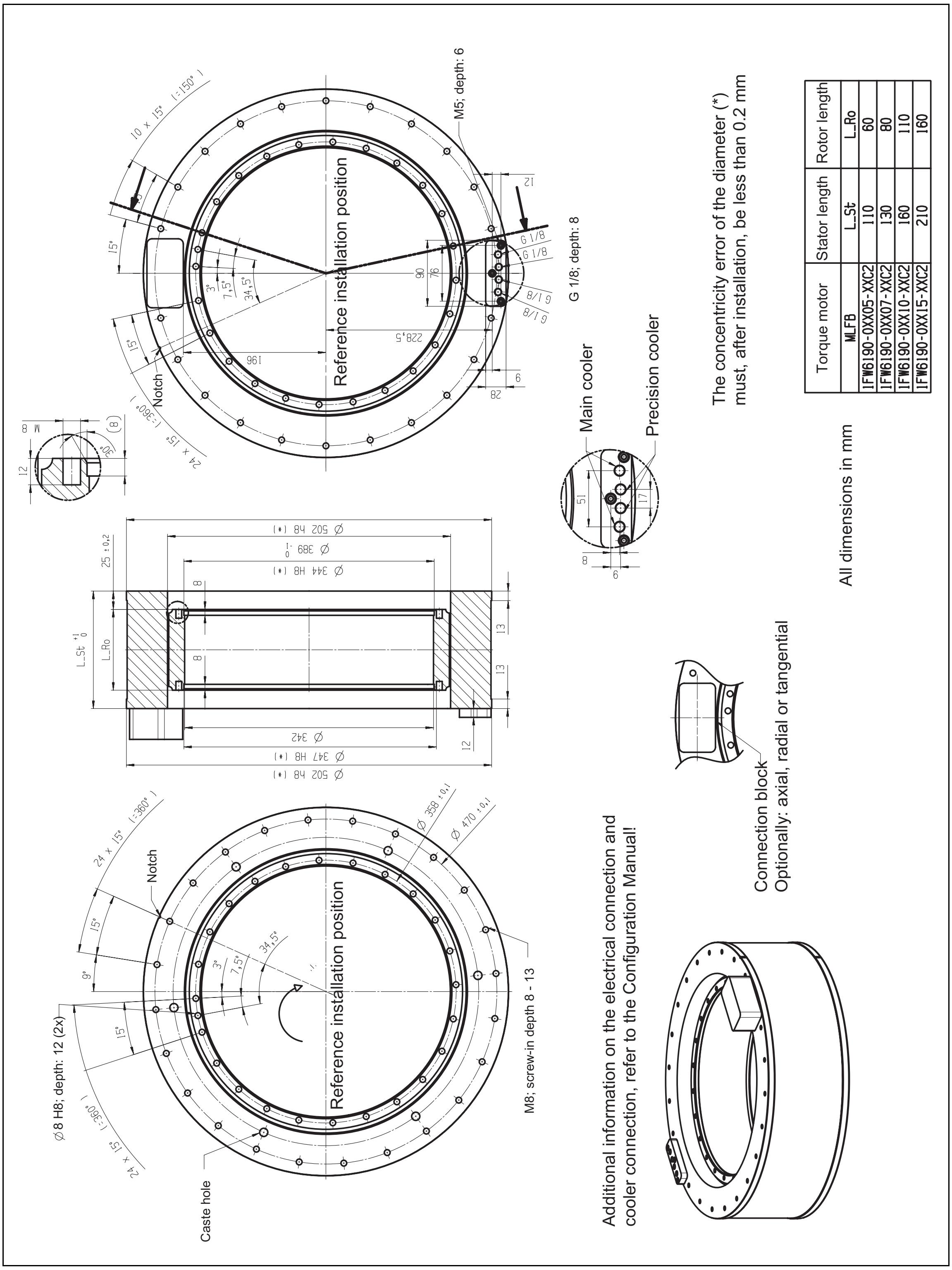


Figure 6-3: 1FW6130-...



Torque motor	Stator length	Rotor length
MLFB	L_St	L_Ro
1FW6160-0XX05-XXC2	110	60
1FW6160-0XX07-XXC2	130	80
1FW6160-0XX10-XXC2	160	110
1FW6160-0XX15-XXC2	210	160

Figure 6-4: 1FW6160-...



Torque motor MLFB	Stator length L_St	Rotor length L_Ro
1FW6190-0XX05-XXC2	110	60
1FW6190-0XX07-XXC2	130	80
1FW6190-0XX10-XXC2	160	110
1FW6190-0XX15-XXC2	210	160

Figure 6-5: 1FW6190-...

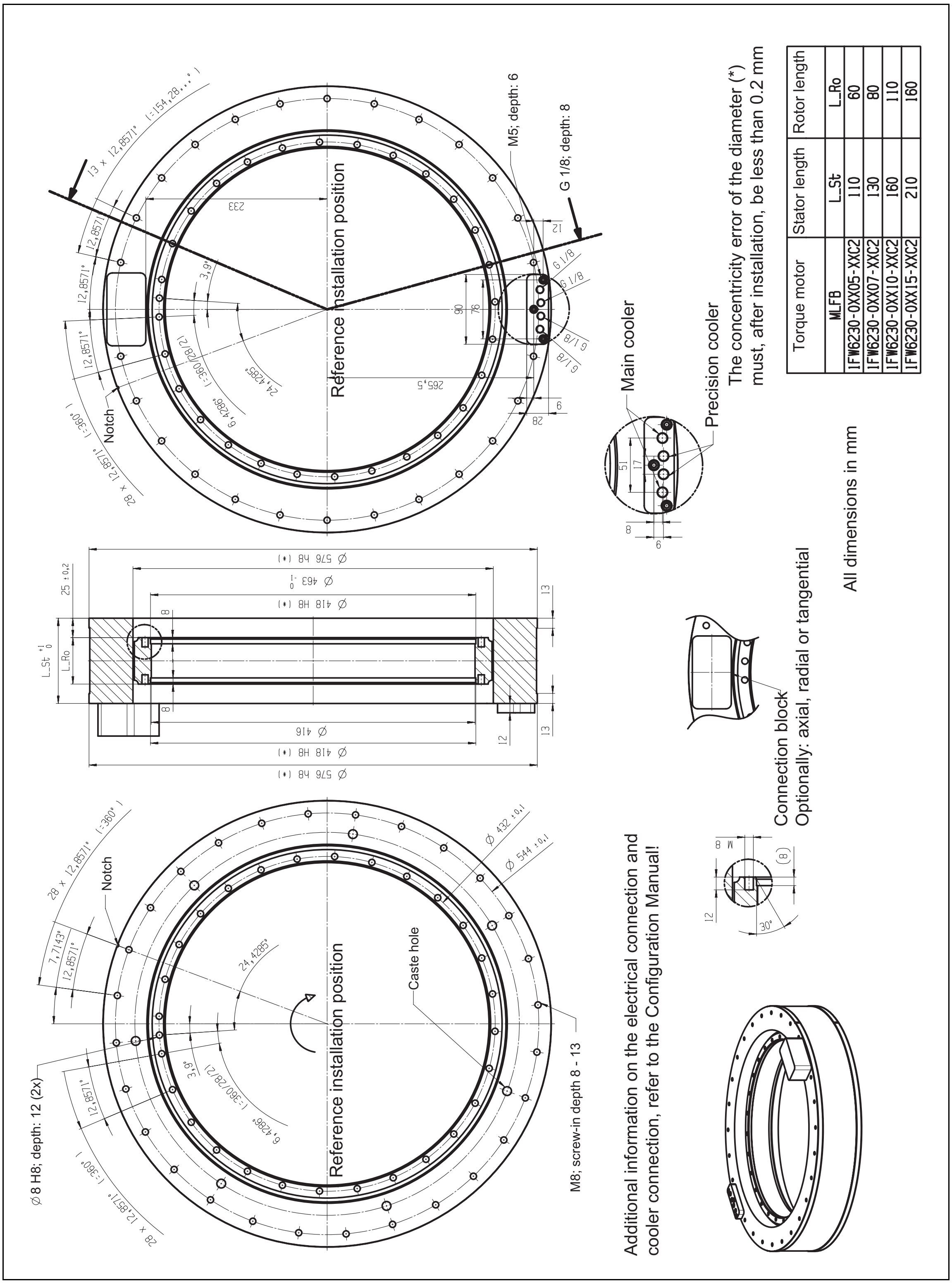


Figure 6-6: 1FW6230-...

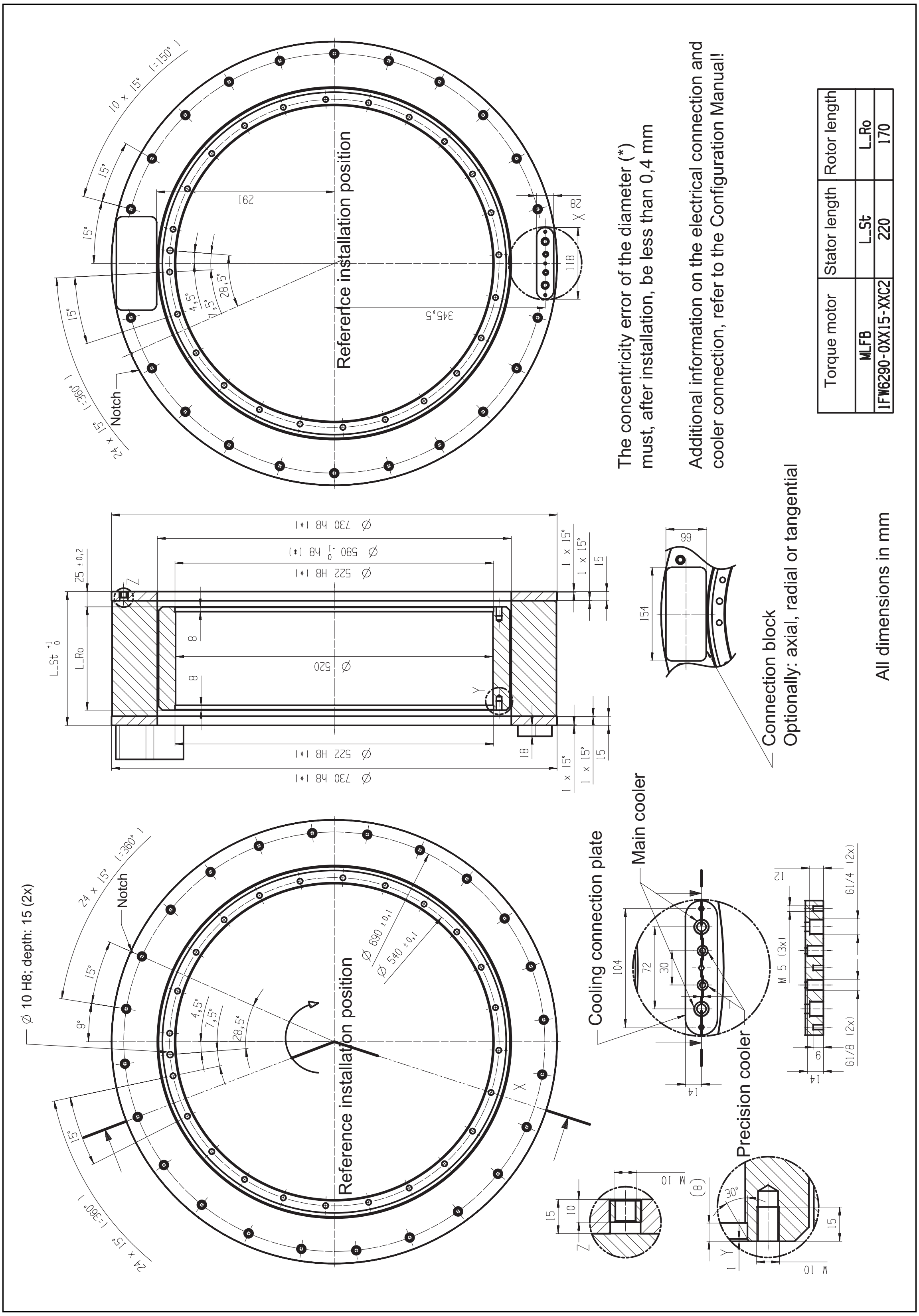


Figure 6-7: 1FW6290-..

7

7 Inspection, Maintenance, Disposal

7.1 Inspection, maintenance

Warning

It is very important that you carefully observe the safety information and instructions in this Configuration Manual.

Torque motors are essentially maintenance-free. You will extend the lifetime of your motor ifyou carefully observe the following information and instructions:

- regularly check that the rotary axis is free to move
- keep the air gap free of chips and particles (foreign bodies)
- regularly check the general state and condition of the motor components
- check the current drawn in a previously defined test cycle

Operating situations and characteristics can vary widely. For this reason no maintenance intervals can be specified here.

Warning

There is a danger of burns when coming into contact with hot surfaces if inspection or maintenance work is immediately carried-out at the motor after it has just been operated. The cooling water temperature can still continue to increase even if the motor has already been powered-down.

In order that the motor can cool-down to about the level of the intake temperature T_{INTAKE}, the cooling must remain operational for at least 30 minutes after the motor has been powered-down. However, if the cooling is also powered-down then it takes a significantly longer time for the motor to cool down. In this case the mounting situation plays a significant role.

Dirt - e.g. chips, oils etc. - must be kept away from the area in which the motor is installed. Depending on the local degree of pollution, clean the motor in order to ensure perfect operation and to guarantee that the power loss is adequately dissipated.

Cables must be checked for damage and wear. Electrical equipment and devices with damaged cables may not be used.

Check that the cable glands are tight.

Signs that indicate that service & maintenance are required

- dirt in the motor area
- visible differences regarding the machine behavior
- audible differences regarding the machine behavior
- the workpiece quality has significantly deteriorated

7.2 Disposal

You may only dispose of torque motors or their components if it is ensured that they will be correctly disposed of.

In particular, this includes:

- de-magnetization of the rotor
- recycling components (if possible)
- professionally disposing of electrical waste

In order to ensure that the manufacturer can professionally dispose of the torque motors and components they may only be returned to the manufacturer in their original packaging. The party/company returning the motor bears the costs for shipping and disposal.

Original packaging materials can be requested from your local Siemens office.

7.2.1 Disposing of 1FW6 rotors

The rotors equipped with magnets must be subject to a special thermal process so that during and after disposal the rotors do not pose any potential danger. In order to ensure this, a specialized disposal company must carry-out this work.

After the motor has been disassembled, it is absolutely necessary that the rotors are individually packaged in the undamaged original rotor packaging materials in-line with the specifications and regulations.

Danger

As a result of the strong magnetic fields rotors that are not packaged can result in personal injury and material damage.

It is absolutely imperative that you observe the Chapter "Safety information and instructions" in this Configuration Manual.

De-magnetizing rotors

Disposal companies that are specialized in de-magnetizing use a special oven for this purpose. The internal components of this disposal oven are manufactured out of non-magnetic materials.

The rotors are put into a tough container that is resistant to heat (e.g. a lattice box) manufactured out of a non-magnetic material and placed in the oven; they are kept here during the complete de-magnetization procedure. The temperature in the oven must be at least 300°C and be maintained at this temperature for at least 30 min.

Gases and vapors that are released must be trapped and treated so that they cannot damage the environment.

7.2.2 Disposing electronic components

Electronic parts and components (stator, drive converter, cables etc.) must be professionally disposed as electronic waste.

7.2.3 Disposing the packaging

The packaging and other materials that we use do not contain any problematical materials and substances. With the exception of wooden materials they can be recycled. Wooden materials should be thermally disposed of. Only plastics that can be recycled are used for other packaging materials:

- Code 02 PE-HD (polyethylene)
- Code 02 PE-HD (polyethylene)
- Code 05 PP (polypropylene)
- Code 04 PS (polystyrol)

Space for your notes

A References

A

General Documentation

/BU/ **Catalog NC 60**

Automation Systems for Machine Tools
Ordering information
Order No.: E86060-K4460-A101-B1
Order No.: E86060-K4460-A101-B1 -7600 (English)

Manufacturer/Service Documentation

/PJTM/ **Configuration Manual, Built-in Torque Motors**

SIMODRIVE
1FW6 Built-in Torque Motors
Order No.: 6SN1 197-0AD00-0BP3

/PJAL/ **Configuration Manual, AC Servomotors**

SIMODRIVE
General Part for 1FT/1FK Motors
Order Number: 6SN1 197-0AD07-0BP2

/PFK6/ **Configuration Manual, AC Servomotors**

SIMODRIVE
Three-phase Servomotors 1FK6
Order No.: 6SN1 197-0AD05-0BP0

/PFK7/ **Configuration Manual, AC Servomotors**

SIMODRIVE
Three-phase Servomotors 1FK7
Order No.: 6SN1 197-0AD06-0BP0

/PFT5/ **Configuration Manual, AC Servomotors**

SIMODRIVE
Three-phase Servomotors 1FT5
Order No.: 6SN1 197-0AD01-0BP0

/PFT6/ **Configuration Manual, AC Servomotors**

SIMODRIVE
Three-phase Servomotors 1FT6
Order No.: 6SN1 197-0AD02-0BP0

/PPH/ **Configuration Manual, AC Induction Motors**

SIMODRIVE
AC Induction Motors for 1PH2 Main Spindle Drives
Order No.: 6SN1197-0AC63-0BP0

/PPH/ **Configuration Manual, AC Induction Motors**

SIMODRIVE
AC Induction Motors for 1PH4 Main Spindle Drives
Order No.: 6SN1197-0AC64-0BP0

/PPH/ **Configuration Manual, AC Induction Motors**

SIMODRIVE
AC Induction Motors for 1PH7 Main Spindle Drives
Order No.: 6SN1197-0AC65-0BP1

/PJFE/ **Configuration Manual, Synchronous Built-in Motors**

SIMODRIVE
AC Motors for Main Spindle Drives
Synchronous Built-in Motors 1FE1
Order No.: 6SN1 197-0AC00-0BP5

/PPM/ **Configuration Manual Hollow Shaft Motors**

SIMODRIVE
Hollow-Shaft Motors for Main Spindle Drives 1PM6/1PM4
Order No.: 6SN1 197-0AD03-0BP0

/PJLM/ **Configuration Manual, Linear Motors**

SIMODRIVE
1FN1, 1FN3 Linear Motors
Order No.: 6SN1 197-0AB70-0BP5

/PJU/ **Configuration Manual, Drive Converters**

SIMODRIVE 611
Order No.: 6SN1 197-0AA00-0BP7

/EMV/ **Configuration Manual EMC Guidelines**

SINUMERIK, SIROTEC, SIMODRIVE
Order No.: 6FC5 297–0AD30–0BP2

/GH/ **Manual**

SIMODRIVE
SME9x Sensor Module External
Order No.: none, only available as file

Electronic documentation

/CD1/ **DOC ON CD**

The SINUMERIK System
(includes all SINUMERIK 840D/840Di/810D/802 and SIMODRIVE publications)
Order No.: 6FC5 298-0CD00-0AG0

Space for your notes

B Abbreviations

B

EMF	Electromotive force
EMC	Electromagnetic compatibility
HFD	High-frequency commutating reactor for damping
inc.	incremental
LT	Power unit
MLFB	Machine Readable Product Designation, Order No.
PU	Polyurethane, material with a high resistance to wear
RLI	Rotor position identification (also called pole position identification); technique to determine the angular commutation offset
Software	Software release
TPE	Halogen-free polyethylene
WMS	Angle measuring system

Space for your notes

C

C Manufacturer Recommendations

Notice

We do not guarantee the characteristics and quality of third-party products.
Please carefully observe the detailed text in the Foreword.

Table C-1: Sources for purchasing connection parts and components and accessories for the cooling systems (status, August 2005)

Company	Address	Tel. No./FAX No./Internet/e-mail
RECTUS GMBH	Daimlerstrasse 7 D-71735 Eberdingen-Nussdorf	Phone: +49 (0) 7042 1000 Fax: +49 (0) 7042 100 47 Internet: www.rectus.de e-mail: info@rectus.de
FESTO AG & Co. KG	Ruiter Strasse 82 D-73734 Esslingen - Berkheim	Phone: +49 (0) 1 80 / 3 03 11 11 Fax: +49 (0) 7 11 / 3 47 26 28 Internet: www.festo.com e-mail: info_de@festo.com
SERTO JACOB GMBH	Kasseler Straße 64 D-34277 Fuldabrück	Phone: +49 (0) 561 58 004 0 Fax: +49 (0) 561 58 004 44 Internet: www.serto.com
SMC PNEUMATIK GMBH	Boschring 13 -15 D-63329 Egelsbach	Phone: +49 (0) 6103 402 0 Fax: +49 (0) 6103 402 139 Internet: www.smc-pneumatik.de e-mail: info@smc-pneumatik.de

Table C-2: Cooling system manufacturers (status, August 2005)

Company	**Address**	**Tel. No./FAX No./Internet/e-mail**
BKW Kälte-Wärme-Versorgungstechnik GmbH	Benzstrasse 2 D-72645 Wolfschlugen	Phone: +49 (0) 7022 - 5003 - 0 Fax: +49 (0) 7022 - 5003 - 30 e-mail: info@bkw-kuema.de Internet: bkw-kuema.de
Helmut Schimpke und Team Industriekühlanlagen GmbH + Co. KG	Ginsterweg 25-27 D- 42781 Haan	Phone: +49 (0) 2129 - 9438 - 0 Fax: +49 (0) 2129 - 9438 - 99 e-mail: info@schimpke.de Internet: www.schimpke.de
Hydac System GmbH	Postfach 12 51 D-66273 Sulzbach/Saar	Phone: +49 (0) 6897 - 509 -708 Fax: +49 (0) 6897 - 509 - 454 e-mail: winfried.klein@hydac.com Internet: www.hydac.com
Pfannenberg GmbH	Werner-Witt-Straße 1 D-21035 Hamburg	Phone: +49 (0) 40 - 73412 - 0 Fax: +49 (0) 40 - 73412 - 101 e-mail: sven.gerstenkorn@pfannenberg.com Internet: www.pfannenberg.com
Rittal GmbH & Co. KG	Postfach 1662 D-35726 Herborn	Phone: +49 (0) 2772 - 505 - 2527 Fax: +49 (0) 2772 - 505 - 2537 Internet: www.rittal.de

Table C-3: Anti-corrosion agent manufacturers (status, August 2005)

Company	**Address**	**Tel. No./FAX No./Internet/e-mail**
TYFOROP CHEMIE GmbH	Anton-Rée-Weg 7 D-20537 Hamburg	Tel: +49 40 209497-0 Internet: www.tyfo.de

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To SIEMENS AG A&D MC MS Postfach 3180 D-91050 Erlangen Federal Republic of Germany Phone: +49 (0) 180 5050 – 222 [Hotline] Fax: +49 (0) 9131 98 – 63315 [Documentation] mailto:motioncontrol.docu@siemens.com	Suggestions Corrections For Publication: SIMODRIVE Configuration Manual
From Name	1FW6 Built-in Torque Motors Order No.: 6SN1197-0AD00-0BP3 02/2006 Edition
Address of your company/department Address:	Should you come across any printing errors when reading this publication, please notify us on this sheet. Suggestions for improvements are also welcomed.
Postal code: City:	
Telephone: /	
Telefax: /	

Suggestions and/or corrections