Electric Drives and Controls | Hydraulics | Linear Motion and Assembly Technologies | Pneumatics | Service

Rexroth Bosch Group

# Rexroth IndraDyn L Synchronous Linear Motors

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## Project Planning Manual

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# Table of Contents

Table of Contents

Table of Contents

Page

Table of Contents

Table of Contents

Page

Table of Contents

Page

Table of Contents

Table of Contents

# 1 Introduction to the Product

## 1.1 Application Range of Linear Direct Drives

New technologies with a high economic use, demand more and more numeric driven movements with partly extreme standards on acceleration, speed and exactness.

Conventional NC-drives, consisting of a rotating electrical motor and mechanical transmission elements like gearboxes, belt transmissions or gear rack pinions, cannot fulfill these demands or, if only with high effort.

In many cases, the linear direct drive technology is an optimal alternative providing significant benefits:

- High velocity and acceleration
- Excellent control quality and positioning behavior
- Direct power transfer – no mechanical transmission elements like ball srew, toothed belt, gear rack, etc.
- Maintenance-free drive (no wearing parts at the motor)
- Simplified machine structure
- High static and dynamic load rigidity

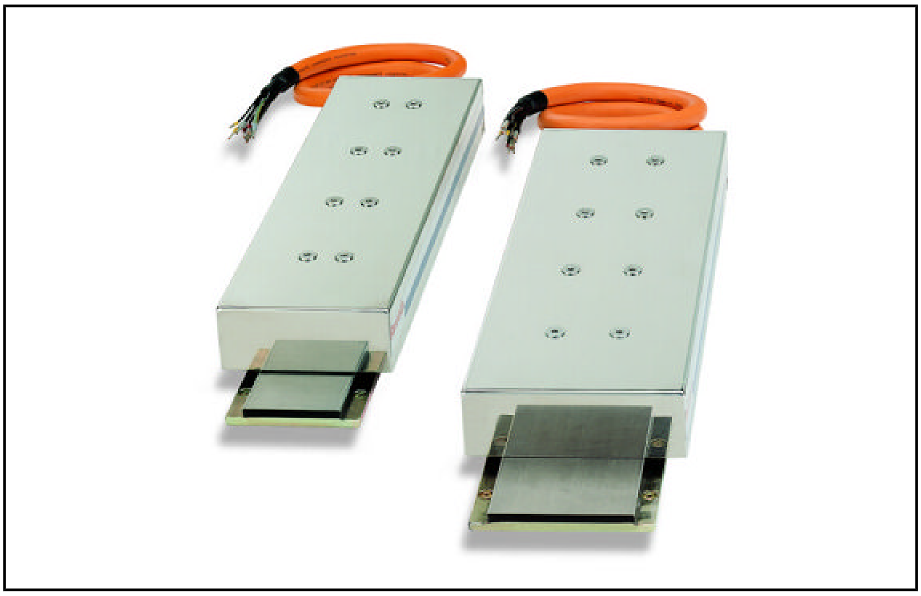

*Fig. 1-1: Illustration example IndraDyn L*

Due to the direct installation in to the machine, there are no wearing mechanical components, making a power train with no backlash or minimized backlash available. This permits very high control qualities with a gain in the position control loop (Kv factor) of more than 20 m/min/mm to be reached.

In conventional electromagnetic systems, positioning tasks with high feed rates or highly accelerated short-stroke movements in quick succession lead to a premature deterioration of mechanical parts and thus to loss and significant costs. In these applications linear direct drives offer decisive advantages.

Starting from the above-mentioned benefits, there are the following application ranges for linear synchronous direct drives:

- High-speed cutting in transfer lines and machining centers
- Grinding, in particular camshaft and crankshaft machining

Introduction to the Product

- Laser machining
- Precision and ultra-precision machining,
- Sheet-metal working,
- Handling, textile and packaging machines
- Free form surface machining
- Wood machining,
- Printed circuit board machining,
- ......

Due to a practice-oriented combination of motor technology with intelligent digital drive controllers the linear direct drive technique offers new solutions with significantly improved performance.

The development status of the synchronous linear technique of Bosch Rexroth permits a very high force density.

The spectrum of Bosch Rexroth synchronous linear drive technology, which is described below, permits feed drive systems of 250 N up to 21.000 N per motor and speed over 600 m/min.

The following diagram gives an overview of the performance spectrum of the Bosch Rexroth motors type IndraDyn L.

**Performance List**

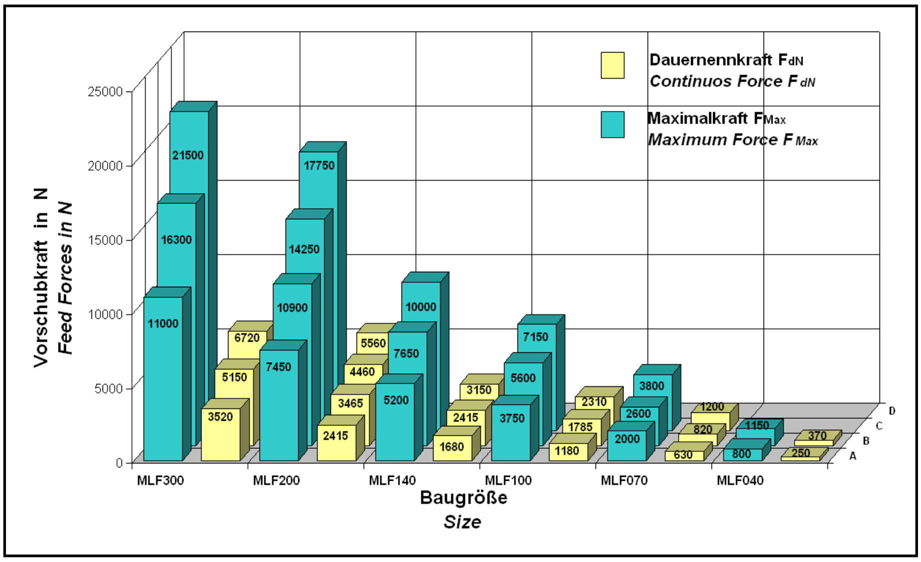


*Fig.1-2: Performance spectrum IndraDyn L motors*

# 1.2 About this Documentation

## 1.2.1 Document Structure

This documentation includes safety regulations, technical data and operating instructions. The following table provides an overview of the contents of this documentation.

| Chapter | Title | Contents |
|---|---|---|
| 1 | Introduction | Product presentaion / Notes regarding reading |
| 2 | Important Instructions on Use | **Important Safety Notes** |
| 3 | Safety | |

<table>
<tr><th>Chapter</th><th>Title</th><th colspan="4">Contents</th></tr>
<tr><td>4</td><td>Technical Data</td><td rowspan="8">Product Description</td><td rowspan="8">for planners and designers</td><td></td><td></td></tr>
<tr><td>5</td><td>Specifications</td><td></td><td></td></tr>
<tr><td>6</td><td>Type Codes</td><td></td><td></td></tr>
<tr><td>7</td><td>Accessories</td><td rowspan="9">Practice</td><td rowspan="9">for operating and maintenance personnel</td></tr>
<tr><td>8</td><td>Connection Technique</td></tr>
<tr><td>9</td><td>Operating Condition and Application Instructions</td></tr>
<tr><td>10</td><td>Motor-Control-Combination</td></tr>
<tr><td>11</td><td>Motor dimensioning</td></tr>
<tr><td>12</td><td>Handling, Transport and Storage</td><td></td><td></td></tr>
<tr><td>13</td><td>Installation</td><td></td><td></td></tr>
<tr><td>14</td><td>Startup, Operation and Maintenance</td><td></td><td></td></tr>
<tr><td>15</td><td>Service & Support</td><td></td><td></td></tr>
<tr><td>16</td><td>Appendix</td><td colspan="4" rowspan="2">Additional information</td></tr>
<tr><td>17</td><td>Index</td></tr>
</table>

*Fig. 1-3: Chapter structure*

## 1.2.2 Additional Documentation

For project planning your drive systems with motors of the IndraDyn A series you will possible need additional documentation, according to the devices used. Rexroth provides the entire product documentation in the Bosch Rexroth media directory (in PDF format) under http://www.boschrexroth.com/various/utilities/mediadirectory/index.jsp.

## 1.2.3 Additional Components

Documentation for external systems which are connected to Bosch Rexroth components are not included in the scope of delivery and must be ordered directly from the corresponding manufacturers.

For information about the manufacturers see chapter 16 ”Appendix”

## 1.2.4 Your Feedback

Your experiences are an essential part of the process of improving both the product and the documentation.

Please do not hesitate to inform us of any mistakes you detect in this documentation or of any modifications you might desire. We would appreciate your feedback.

Please send your remarks to:

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## 1.2.5 Standards

This documentation refers to German, European and international technical standards. Documents and sheets on standards are subject to copyright protection and may not be passed on to third parties by Rexroth. If need be, please contact the authorized sales outlets or, in Germany, directly:

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# 2 Important Instructions on Use

## 2.1 Appropriate Use

### 2.1.1 Introduction

Bosch Rexroth products are designed and manufactured using the latest state-of-the-art-technology. Before they are delivered, they are inspected to ensure that they operate safely.

The products must only be used as intended. If they are not used as intended, situations may arise that result in personal injuries or damage to property.

☞ For damage caused by products not being used as intended, Bosch Rexroth gives no warranty, assumes no liability, and will not pay for any damages. Any risks resulting from the products not being used as intended are the sole responsibility of the user.

Before using the Bosch Rexroth products, the following condition precedent must be fulfilled so as to ensure that they are used as intended:

- Everyone who in any way whatsoever handles one of our products must read and understand the corresponding notes regarding safety and regarding the intended use.
- If the products are hardware, they must be kept in their original state, i.e. no constructional modifications must be made. Software products must not be decompiled; their source codes must not be modified.
- Damaged or improperly working products must not be installed or put into operation.
- It must be ensured that the products are installed according to the regulations specified in the documentation.

### 2.1.2 Areas of Use and Application

Synchronous linear motors of the IndraDyn L series of Bosch Rexroth are determined to be used as linear servo drive motors.

Drive device types with different driving powers and different interfaces are available for an application-specific use of the motors.

It is necessary to control and monitor the motors to connect additional sensors, e.g. length measuring systems.

☞
- The motors must only be used with the accessories specified in this documentation. Components that are not explicitly mentioned must neither be attached nor connected. The same is true for cables and lines.
- The operation must only be carried out in the explicitly mentioned configurations and combinations of the component and with the software and firmware specified in the corresponding functional description.

Any connected drive control device must be programmed before startup in order to ensure that the motor executes the functions specifically to the particular application.

The motors may only be operated under the assembly, mounting and installation conditions, in the normal position, and under the environmental conditions (temperature, degree of protection, humidity, EMC etc.) specified in this documentation.

## 2.2 Inappropriate Use

Any use of the motors outside of the fields of application mentioned above or under operating conditions and technical data other than those specified in this documentation is considered to be ”inappropriate use”.

IndraDyn L motors must not be used if:

- They are subject to operating conditions which do not comply with the ambient conditions described above. E.g. operation under water, under extreme variations in temperature or extreme maximum temperatures is not permitted.
- The intended fields of application have not been expressly released for the motors by Bosch Rexroth. Please make absolutely sure that the instructions given in the general safety notes are also complied with!

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☞ IndraDyn L motors are not suited to be operated directly on the power supply.

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# 3 Safety Instructions for Electric Drives and Controls

## 3.1 Safety Instructions - General Information

### 3.1.1 Using the Safety Instructions and Passing them on to Others

Do not attempt to install or commission this device without first reading all documentation provided with the product. Read and understand these safety instructions and all user documentation prior to working with the device. If you do not have the user documentation for the device, contact your responsible Bosch Rexroth sales representative. Ask for these documents to be sent immediately to the person or persons responsible for the safe operation of the device.

If the device is resold, rented and/or passed on to others in any other form, these safety instructions must be delivered with the device in the official language of the user's country.

---

WARNING

**Improper use of these devices, failure to follow the safety instructions in this document or tampering with the product, including disabling of safety devices, may result in material damage, bodily harm, electric shock or even death!**

Observe the safety instructions!

---

### 3.1.2 How to Employ the Safety Instructions

Read these instructions before initial commissioning of the equipment in order to eliminate the risk of bodily harm and/or material damage. Follow these safety instructions at all times.

- Bosch Rexroth AG is not liable for damages resulting from failure to observe the warnings provided in this documentation.
- Read the operating, maintenance and safety instructions in your language before commissioning the machine. If you find that you cannot completely understand the documentation for your product, please ask your supplier to clarify.
- Proper and correct transport, storage, assembly and installation, as well as care in operation and maintenance, are prerequisites for optimal and safe operation of this device.
- Only assign trained and qualified persons to work with electrical installations:
  - Only persons who are trained and qualified for the use and operation of the device may work on this device or within its proximity. The persons are qualified if they have sufficient knowledge of the assembly, installation and operation of the product, as well as an understanding of all warnings and precautionary measures noted in these instructions.
  - Furthermore, they must be trained, instructed and qualified to switch electrical circuits and devices on and off in accordance with technical safety regulations, to ground them and to mark them according to the requirements of safe work practices. They must have adequate safety equipment and be trained in first aid.
- Only use spare parts and accessories approved by the manufacturer.

- Follow all safety regulations and requirements for the specific application as practiced in the country of use.
- The devices have been designed for installation in industrial machinery.
- The ambient conditions given in the product documentation must be observed.
- Only use safety-relevant applications that are clearly and explicitly approved in the Project Planning Manual. If this is not the case, they are excluded. Safety-relevant are all such applications which can cause danger to persons and material damage.
- The information given in the documentation of the product with regard to the use of the delivered components contains only examples of applications and suggestions.

  The machine and installation manufacturer must

  – make sure that the delivered components are suited for his individual application and check the information given in this documentation with regard to the use of the components,
  – make sure that his application complies with the applicable safety regulations and standards and carry out the required measures, modifications and complements.
- Commissioning of the delivered components is only permitted once it is sure that the machine or installation in which they are installed complies with the national regulations, safety specifications and standards of the application.
- Operation is only permitted if the national EMC regulations for the application are met.
- The instructions for installation in accordance with EMC requirements can be found in the section on EMC in the respective documentation (Project Planning Manuals of components and system).

  The machine or installation manufacturer is responsible for compliance with the limiting values as prescribed in the national regulations.
- Technical data, connection and installation conditions are specified in the product documentation and must be followed at all times.

*National regulations which the user must take into account*

- European countries: according to European EN standards
- United States of America (USA):
  – National Electrical Code (NEC)
  – National Electrical Manufacturers Association (NEMA), as well as local engineering regulations
  – regulations of the National Fire Protection Association (NFPA)
- Canada: Canadian Standards Association (CSA)
- Other countries:
  – International Organization for Standardization (ISO)
  – International Electrotechnical Commission (IEC)

### 3.1.3 Explanation of Warning Symbols and Degrees of Hazard Seriousness

The safety instructions describe the following degrees of hazard seriousness. The degree of hazard seriousness informs about the consequences resulting from non-compliance with the safety instructions:

| Warning symbol | Signal word | Degree of hazard seriousness acc. to ANSI Z 535.4-2002 |
|---|---|---|
| | Danger | Death or severe bodily harm will occur. |
| | Warning | Death or severe bodily harm may occur. |
| | Caution | Minor or moderate bodily harm or material damage may occur. |

*Fig.3-1: Hazard classification (according to ANSI Z 535)*

## 3.1.4 Hazards by Improper Use

DANGER

**High electric voltage and high working current! Risk of death or severe bodily injury by electric shock!**

Observe the safety instructions!

DANGER

**Dangerous movements! Danger to life, severe bodily harm or material damage by unintentional motor movements!**

Observe the safety instructions!

WARNING

**High electric voltage because of incorrect connection! Risk of death or bodily injury by electric shock!**

Observe the safety instructions!

WARNING

**Health hazard for persons with heart pacemakers, metal implants and hearing aids in proximity to electrical equipment!**

Observe the safety instructions!

CAUTION

**Hot surfaces on device housing! Danger of injury! Danger of burns!**

Observe the safety instructions!

CAUTION

**Risk of injury by improper handling! Risk of bodily injury by bruising, shearing, cutting, hitting or improper handling of pressurized lines!**

Observe the safety instructions!

CAUTION

**Risk of injury by improper handling of batteries!**

Observe the safety instructions!

## 3.2 Instructions with Regard to Specific Dangers

### 3.2.1 Protection Against Contact with Electrical Parts and Housings

☞ This section concerns devices and drive components with voltages of **more than 50 Volt**.

Contact with parts conducting voltages above 50 Volts can cause personal danger and electric shock. When operating electrical equipment, it is unavoidable that some parts of the devices conduct dangerous voltage.

DANGER

**High electrical voltage! Danger to life, electric shock and severe bodily injury!**

- Only those trained and qualified to work with or on electrical equipment are permitted to operate, maintain and repair this equipment.
- Follow general construction and safety regulations when working on power installations.
- Before switching on the device, the equipment grounding conductor must have been non-detachably connected to all electrical equipment in accordance with the connection diagram.
- Do not operate electrical equipment at any time, even for brief measurements or tests, if the equipment grounding conductor is not permanently connected to the mounting points of the components provided for this purpose.
- Before working with electrical parts with voltage potentials higher than 50 V, the device must be disconnected from the mains voltage or power supply unit. Provide a safeguard to prevent reconnection.
- With electrical drive and filter components, observe the following:

  Wait **30 minutes** after switching off power to allow capacitors to discharge before beginning to work. Measure the electric voltage on the capacitors before beginning to work to make sure that the equipment is safe to touch.
- Never touch the electrical connection points of a component while power is turned on. Do not remove or plug in connectors when the component has been powered.
- Install the covers and guards provided with the equipment properly before switching the device on. Before switching the equipment on, cover and safeguard live parts safely to prevent contact with those parts.
- A residual-current-operated circuit-breaker or r.c.d. cannot be used for electric drives! Indirect contact must be prevented by other means, for example, by an overcurrent protective device according to the relevant standards.
- Secure built-in devices from direct touching of electrical parts by providing an external housing, for example a control cabinet.

For electrical drive and filter components with voltages of **more than 50 volts**, observe the following additional safety instructions.

DANGER

**High housing voltage and high leakage current! Risk of death or bodily injury by electric shock!**

- Before switching on, the housings of all electrical equipment and motors must be connected or grounded with the equipment grounding conductor to the grounding points. This is also applicable before short tests.
- The equipment grounding conductor of the electrical equipment and the devices must be non-detachably and permanently connected to the power supply unit at all times. The leakage current is greater than 3.5 mA.
- Over the total length, use copper wire of a cross section of a minimum of 10 $mm^2$ for this equipment grounding connection!
- Before commissioning, also in trial runs, always attach the equipment grounding conductor or connect to the ground wire. Otherwise, high voltages may occur at the housing causing electric shock.

## 3.2.2 Protection Against Electric Shock by Protective Extra-Low Voltage

Protective extra-low voltage is used to allow connecting devices with basic insulation to extra-low voltage circuits.

All connections and terminals with voltages between 5 and 50 volts at Rexroth products are PELV systems. [1] It is therefore allowed to connect devices equipped with basic insulation (such as programming devices, PCs, notebooks, display units) to these connections and terminals.

WARNING

**High electric voltage by incorrect connection! Risk of death or bodily injury by electric shock!**

If extra-low voltage circuits of devices containing voltages and circuits of more than 50 volts (e.g. the mains connection) are connected to Rexroth products, the connected extra-low voltage circuits must comply with the requirements for PELV. [2]

## 3.2.3 Protection Against Dangerous Movements

Dangerous movements can be caused by faulty control of connected motors. Some common examples are:

- improper or wrong wiring of cable connections
- incorrect operation of the equipment components
- wrong input of parameters before operation
- malfunction of sensors, encoders and monitoring devices
- defective components
- software or firmware errors

Dangerous movements can occur immediately after equipment is switched on or even after an unspecified time of trouble-free operation.

1) *"Protective Extra-Low Voltage"*

2) *"Protective Extra-Low Voltage"*

The monitoring in the drive components will normally be sufficient to avoid faulty operation in the connected drives. Regarding personal safety, especially the danger of bodily harm and material damage, this alone cannot be relied upon to ensure complete safety. Until the integrated monitoring functions become effective, it must be assumed in any case that faulty drive movements will occur. The extent of faulty drive movements depends upon the type of control and the state of operation.

**DANGER**

**Dangerous movements! Danger to life, risk of injury, severe bodily harm or material damage!**

- Ensure personal safety by means of qualified and tested higher-level monitoring devices or measures integrated in the installation.

  These measures have to be provided for by the user according to the specific conditions within the installation and a hazard and fault analysis. The safety regulations applicable for the installation have to be taken into consideration. Unintended machine motion or other malfunction is possible if safety devices are disabled, bypassed or not activated.

**To avoid accidents, bodily harm and/or material damage:**

- Keep free and clear of the machine's range of motion and moving parts. Possible measures to prevent people from accidentally entering the machine's range of motion:
  - use safety fences
  - use safety guards
  - use protective coverings
  - install light curtains or light barriers
- Fences and coverings must be strong enough to resist maximum possible momentum.
- Mount the emergency stop switch in the immediate reach of the operator. Verify that the emergency stop works before startup. Don't operate the device if the emergency stop is not working.
- Isolate the drive power connection by means of an emergency stop circuit or use a safety related starting lockout to prevent unintentional start.
- Make sure that the drives are brought to a safe standstill before accessing or entering the danger zone.
- Additionally secure vertical axes against falling or dropping after switching off the motor power by, for example:
  - mechanically securing the vertical axes,
  - adding an external braking/ arrester/ clamping mechanism or
  - ensuring sufficient equilibration of the vertical axes.
- The standard equipment motor brake or an external brake controlled directly by the drive controller are **not sufficient to guarantee personal safety**!
- Disconnect electrical power to the equipment using a master switch and secure the switch against reconnection for:
  - maintenance and repair work
  - cleaning of equipment
  - long periods of discontinued equipment use
- Prevent the operation of high-frequency, remote control and radio equipment near electronics circuits and supply leads. If the use of such devices cannot be avoided, verify the system and the installation for possible malfunctions in all possible positions of normal use before initial startup. If necessary, perform a special electromagnetic compatibility (EMC) test on the installation.

### 3.2.4 Protection Against Magnetic and Electromagnetic Fields During Operation and Mounting

Magnetic and electromagnetic fields generated by current-carrying conductors and permanent magnets in motors represent a serious personal danger to those with heart pacemakers, metal implants and hearing aids.

---

**WARNING**

**Health hazard for persons with heart pacemakers, metal implants and hearing aids in proximity to electrical equipment!**

- Persons with heart pacemakers and metal implants are not permitted to enter following areas:
  - Areas in which electrical equipment and parts are mounted, being operated or commissioned.
  - Areas in which parts of motors with permanent magnets are being stored, repaired or mounted.
- If it is necessary for somebody with a pacemaker to enter such an area, a doctor must be consulted prior to doing so. The noise immunity of present or future implanted heart pacemakers differs greatly so that no general rules can be given.
- Those with metal implants or metal pieces, as well as with hearing aids, must consult a doctor before they enter the areas described above. Otherwise health hazards may occur.

---

### 3.2.5 Protection Against Contact with Hot Parts

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**CAUTION**

**Hot surfaces at motor housings, on drive controllers or chokes! Danger of injury! Danger of burns!**

- Do not touch surfaces of device housings and chokes in the proximity of heat sources! Danger of burns!
- Do not touch housing surfaces of motors! Danger of burns!
- According to the operating conditions, temperatures can be **higher than 60 °C**, 140°F during or after operation.
- Before accessing motors after having switched them off, let them cool down for a sufficiently long time. Cooling down can require **up to 140 minutes**! Roughly estimated, the time required for cooling down is five times the thermal time constant specified in the Technical Data.
- After switching drive controllers or chokes off, wait 15 minutes to allow them to cool down before touching them.
- Wear safety gloves or do not work at hot surfaces.
- For certain applications, the manufacturer of the end product, machine or installation, according to the respective safety regulations, has to take measures to avoid injuries caused by burns in the end application. These measures can be, for example: warnings, guards (shielding or barrier), technical documentation.

---

### 3.2.6 Protection During Handling and Mounting

In unfavorable conditions, handling and mounting certain parts and components in an improper way can cause injuries.

CAUTION

**Risk of injury by improper handling! Bodily injury by bruising, shearing, cutting, hitting!**

- Observe the general construction and safety regulations on handling and mounting.
- Use suitable devices for mounting and transport.
- Avoid jamming and bruising by appropriate measures.
- Always use suitable tools. Use special tools if specified.
- Use lifting equipment and tools in the correct manner.
- If necessary, use suitable protective equipment (for example safety goggles, safety shoes, safety gloves).
- Do not stand under hanging loads.
- Immediately clean up any spilled liquids because of the danger of skidding.

## 3.2.7 Battery Safety

Batteries consist of active chemicals enclosed in a solid housing. Therefore, improper handling can cause injury or material damage.

CAUTION

**Risk of injury by improper handling!**

- Do not attempt to reactivate low batteries by heating or other methods (risk of explosion and cauterization).
- Do not recharge the batteries as this may cause leakage or explosion.
- Do not throw batteries into open flames.
- Do not dismantle batteries.
- When replacing the battery/batteries do not damage electrical parts installed in the devices.
- Only use the battery types specified by the manufacturer.

☞ Environmental protection and disposal! The batteries contained in the product are considered dangerous goods during land, air, and sea transport (risk of explosion) in the sense of the legal regulations. Dispose of used batteries separate from other waste. Observe the local regulations in the country of assembly.

## 3.2.8 Protection Against Pressurized Systems

According to the information given in the Project Planning Manuals, motors cooled with liquid and compressed air, as well as drive controllers, can be partially supplied with externally fed, pressurized media, such as compressed air, hydraulics oil, cooling liquids and cooling lubricating agents. Improper handling of the connected supply systems, supply lines or connections can cause injuries or material damage.

CAUTION

**Risk of injury by improper handling of pressurized lines!**

- Do not attempt to disconnect, open or cut pressurized lines (risk of explosion).
- Observe the respective manufacturer's operating instructions.
- Before dismounting lines, relieve pressure and empty medium.
- Use suitable protective equipment (for example safety goggles, safety shoes, safety gloves).
- Immediately clean up any spilled liquids from the floor.

☞ Environmental protection and disposal! The agents used to operate the product might not be economically friendly. Dispose of ecologically harmful agents separately from other waste. Observe the local regulations in the country of assembly.

# 4 Technical Data IndraDyn L

## 4.1 Explanation to Technical Data

### 4.1.1 General Information

All relevant technical motor data as well as the functional principle of this motors are given on the following pages in terms of tables and characteristic curves. The following interdependence was noticed:

- Size and length of the primary part
- Winding mode primary part
- Available power supply or DC bus voltage

☞ All given data and characteristic curves relate on the following conditions – unless otherwise noted:

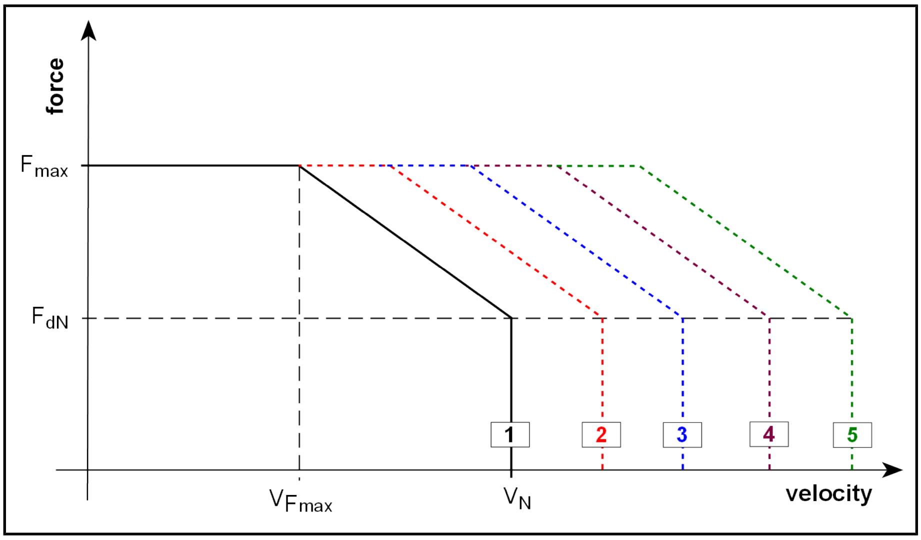
- Motor-winding temperature 135 °C.
- Nominal air gap
- Cooling method water, supply temperature 30 °C

☞ Resulting data from certain motor-controller combinations can differ from the given data. See chapter 10 Motor-controller combinations.

### 4.1.2 Operating Behavior

The characteristic force over speed is given as a limiting curve. The path and the basic data of this characteristic curves are defined by the level of the DC bus voltage and the appropriate motor-specific data as inductivity, resistor and the motor constant. By varying the DC bus voltage (different control devices, supply modules and connected loads) and different motor windings result in different characteristic curves.

Technical Data IndraDyn L




[1] Modular drive controller HMS/HMD at power supply HMV or compact drive controller HCS with power supply 3xAC 400V (medium DC bus voltage, unregulated UDC = 540V)

[2] Modular drive controller HMS/HMD at power supply HMV or compact drive controller HCS with power supply 3xAC 440V (medium DC bus voltage, unregulated UDC = 600V)

[3] Modular drive controller HMS/HMD at power supply HMV or compact drive controller HCS with power supply 3xAC 480V (medium DC bus voltage, unregulated UDC = 650V)

[4] Modular drive controller HMS/HMD at power supply HMV with power supply 3x AC 480V (DC bus voltage, regulated UDC =650V)

[5] Modular drive controller HMS/HMD at power supply HMV with power supply 3x AC 400...480V (DC bus voltage, regulated UDC =750V)

*Fig.4-1: Example motor characteristic curve*

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☞ The achievable torque depends on the drive controller used. The reference value for the technical data and the figured characteristic curves of the motor, is an unregulated DC bus voltage of 540 $V_{DC}$.

---

The maximum force $F_{MAX}$ is available up to a speed $v_{FMAX}$. When the velocity rises, the available DC bus voltage is reduced by the velocity-dependent back electromotive force of the motor. This leads to a reduction of the maximum feed force at rising velocity. The characteristic curves are specified up to the continuous nominal force. The velocity that belongs to the continuous nominal force is known as nominal velocity $v_N$.

---

☞ The specified characteristic curves can linearly be converted according to the existing voltages if the connection voltages or DC bus voltages are different.

Where power supply modules with unregulated DC bus voltage are concerned, possible voltage drops must be taken into account that can be caused by simultaneous acceleration of several axes.

---

Example:

$$n_{(U_{DC,neu})} = \frac{U_{DC,neu}}{540V} \cdot n_{nenn}$$

*Fig.4-2: Formula for conversion*

**Conversion to DC bus voltage 750VDC**

$$M_{max750V} = M_{max} = constant \qquad M_{nenn750V} = M_{nenn} = constant$$

$$n_{max750V} = \frac{750V}{540V} \cdot n_{max} \qquad n_{nenn750V} = \frac{750V}{540V} \cdot n_{nenn}$$

*Fig.4-3: Conversion example to DC bus voltage 750VDC*

**Parallel connection of two primary parts at one drive controller**

The following interrelations exist for the parallel connection of two primary parts at one drive controller:

- Doubling of currents and feed forces
  (unless limited by the drive controller)
- Speed $v_{FMAX}$ and $v_{NENN}$ as for single arrangement
- The same motor and voltage constant ($k_{iF}$, $k_E$)
- Halved motor resistances and inductances.

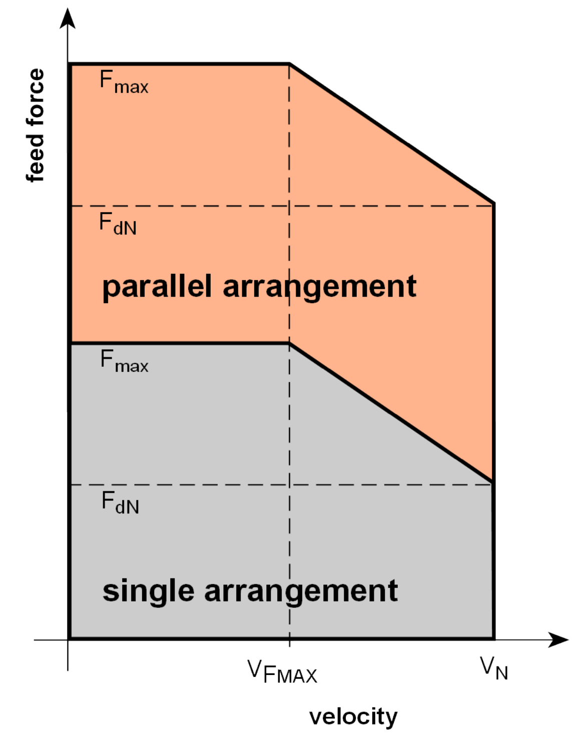



*Fig.4-4: Characteristic curve about force vs. velocity at for single and parallel connection of primary parts to one drive controller*

☞ For the parallel connection of two primary parts to one drive controller this document specifies the corresponding selection data for motor – controller combinations and the motor parameters for commissioning (see chapter 10 "Motor-Controller-Combinations" on page 159 and chapter 14 "Commissioning, Operation and Maintenance" on page 227).

## 4.1.3 Characteristics

**Maximum Force**

$F_{max}$ = Available maximum force at maximum voltage $I_{max}$. Unit Newton [N]. The maximum torque that can be attained depends on the drive control device used.

**Continuous Nominal Force** $F_{dN}$ = Available continuous nominal force in operating mode S1 (contiuous operation) at standstill Unit Newton [N].

**Maximum Current** $I_{max}$ = Maximum voltage (effective value) of the motor at $F_{max}$. Unit Ampère [A].

**Continuous Nominal Voltage** $I_{dN}$ = Phase current (effektive value) of the motor at a nominal velocity and load with continuous nominal force. Unit Ampère [A].

**Maximum Velocity** $v_{Fmax}$ = From the manufacturer defined maximum velocity with maximum force $F_{max}$. Unit [m/min]. The velocity reached depends on the DC bus voltage of the used drive control device.

**Nominal Velocity** $n_N$ = Reachable nominal velocity at contiuous nominal force $F_{dN}$. Unit [m/min]. The velocity reached depends on the DC bus voltage of the used drive control device.

**Force Constant** $K_{iFN}$ = Relation of force increase to rise the force-forming current. Unit [N/A]. Valid up to contiuous nominal current $I_{dN}$.

**Voltage Constant at 20 °C** $K_{EMF}$ = Electromagnetic force. Induced motor voltage (effective value) dependend on the travel velocity regarding the velocity 1m/s. unit [Vs/m].

**Winding Resistance at 20 °C** $R_{12}$ = Measured winding resistance between two strands. Unit Ohm [Ω].

**Winding Inductivity** $L_{12}$ = Measured winding inductivity between two strands. Unit [mH]. The defined measuring values are fluctuating due to boundary effects. The specifications are typical values, determined with a measuring voltage of 1mA at a measuring frequence of 1kHz.

**Necessary Power Wire Cross-Section** $A_L$ = Rated for cables with current rating according to VDE0298-4 (1992) and installation type B2
according to EN 60204-1 (1993) at 40°C ambient temperature. The power wire cross section in mm², specified in the data sheets, can deviate depending on the selected type of connection - plug or terminal box. Therefore, when selecting the appropriate power cable, observe the information in chapter chapter 8 "Electrical Connection" on page 87and the documentation for Rexroth connection cables, MNR R911280894 and MNR R911322948.

**Rated Power Loss** $P_{VN}$ = power loss in operation mode S1 (continuous operation) at nominal velocity $v_N$. Unit Watt [W].

**Nominal Air Gap δ** Measurable nominal air gap between primary and secondary part, specified from the manufacturer. Unit Millimeter [mm].

**Pole Width** $T_P$ = Distance from pole center to pole center of the magnets on the secondary part. Unit Millimeter [mm].

**Attractive Force** $F_{ATT}$ = Maximum attractive force among primary and secondary part at nominal air gap δ and currentless primary part. Unit Newton [N]. Refer to the notes in chapter 9.5 "Feed and Attractive Forces " on page 111.

**Primary Part Mass Standard Encapsulation** $m_{PS}$ = Mass of the primary part with standard encapsulation. Unit Kilogram [kg].

**Primary Part Mass Thermal Encapsulation** $m_{PT}$ = Mass of the primary part with thermo encapsulation. Unit Kilogram [kg].

**Secondary Part Mass** $m_S$ = Mass of the secondary part relating on the length 1 m. Unit [kg/m].

**Required Coolant Flow** $Q_{min}$ = Necessary coolant flow to keep the specified continuous feed force. Unit [l/min]. Heed the notes in chapter 9.6 "Motor Cooling System" on page 116 to determine the coolant flow.

**Constant to Determine the Pressure Loss** $k_{dp}$ = Constant to determine the pressure loss within the motor internal coolant system with coolant water. Heed the notes in chapter 9.6 "Motor Cooling System" on page 116 to determine the pressure loss.

**Pressure Loss Δp at QN**

Pressure loss within the internal coolant circuit of the motor. Heed the notes in chapter 9.6 "Motor Cooling System" on page 116 to determine the pressure loss.

**Permissible Inlet Pressure**

$p_{max}$ = Maximum permitted inlet pressure of the liquid cooling on the motor with coolant water. Unit [bar].

**Coolant Inlet Temperature ϑin**

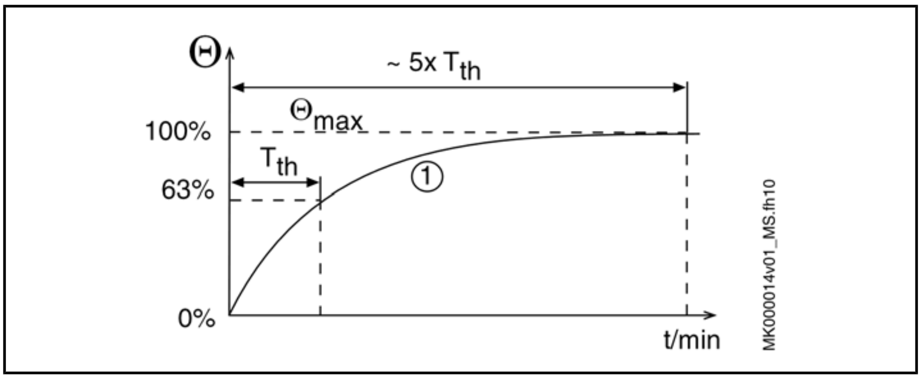
Permissible coolant inlet temperatures. Unit [°C]. The coolant inlet temperature should be maximum 5°C lower than the existing ambient temperature $T_{um}$. At a higher temperature difference, danger of condensation exists! Please, observe the notes in chapter 9.6 "Motor Cooling System" on page 116 about coolant inlet temperature.

**Temperature Rise Δϑ N at PvN**

Temperature difference between coolant inlet and outlet temperature during operation with liquid cooling (coolant water) and rated power loss $P_{vN}$. Unit Kelvin [K].

**Thermal Time Constant**

$T_{th}$ = Duration of the temperature rise to 63 % of the final temperature of the winding under load with continuous nominal force in S1-operation and liquid cooling.




| | |
|---|---|
| ① | Chronological course of the winding temperature |
| $\Theta_{max}$ | Max. winding temperature |
| $T_{th}$ | Thermal time constant |

*Fig.4-5: Thermal time constant*

**Permitted Secondary Part Temperature**

$T_{Smax}$ = Maximum permitted secondary part temperature. Unit [°C].

**Admissible Ambient Temperature during Operation**

$T_{UM}$ = Permitted ambient temperatures. Unit [°C].

**Permissible Storage and Transport Temperature**

$T_L$ = Permissible storage and transport temperatures Unit [°C].

**Degree of Protection**

Protection class according to EN 60034-5.

**Insulation Class**

Insulation class according to EN 60034-1.

## 4.2 Technical Data - Frame Size MLP040

| Description | Symbol | Unit | MLP040 | | | |
|---|---|---|---|---|---|---|
| **Motor data** [1] | | | | | | |
| Frame length | | | A | B | | |
| Winding code | | | 0300 | 0150 | 0250 | 0300 |
| Appropriate secondary parts | | | MLS040S-3A-****-NNNN | | | |
| Maximum force [2] | $F_{max}$ | N | 800 | 1150 | | |
| Continuous nominal force | $F_{dN}$ | N | 250 | 370 | | |
| Maximum current | $I_{max}$ | A | 20 | 20 | 27 | 35 |
| Continuous nominal voltage | $I_{dN}$ | A | 4.2 | 4.2 | 5.3 | 6 |
| Maximum velocity at $F_{max}$ [3] | $v_{Fmax}$ | m/min | 300 | 150 | 250 | 300 |
| Nominal velocity [3] | $v_N$ | m/min | 500 | 300 | 400 | 500 |

Technical Data IndraDyn L

<table>
<tr><th colspan="2">Description</th><th>Symbol</th><th>Unit</th><th colspan="4">MLP040</th></tr>
<tr><td colspan="2">Force constant</td><td>$K_{iFN}$</td><td>N/A</td><td>60</td><td>88</td><td>70</td><td>62</td></tr>
<tr><td colspan="2">Voltage constant [4)]</td><td>$K_{EMF}$</td><td>Vs/m</td><td>38.14</td><td>57</td><td>43</td><td>34</td></tr>
<tr><td colspan="2">Winding resistance at 20°C</td><td>$R_{12}$</td><td>ohms</td><td>8.7</td><td>12.9</td><td>6.5</td><td>5</td></tr>
<tr><td colspan="2">Winding inductivity</td><td>$L_{12}$</td><td>mH</td><td>50</td><td>84</td><td>51</td><td>31</td></tr>
<tr><td colspan="2">Minimum cross-section connection cable [5)]</td><td>$A_{PL}$</td><td>mm²</td><td colspan="4">1.5</td></tr>
<tr><td colspan="2">Rated power loss</td><td>$P_{vN}$</td><td>W</td><td>400</td><td colspan="3">550</td></tr>
<tr><td colspan="2">Nominal air gap</td><td>δ</td><td>mm</td><td colspan="4">$1.0^{+0.55}_{-0.4}$</td></tr>
<tr><td colspan="2">Pole width</td><td>$T_p$</td><td>mm</td><td colspan="4">37.5</td></tr>
<tr><td colspan="2">Attractive force [6)]</td><td>$F_{ATT}$</td><td>N</td><td>1,200</td><td colspan="3">1,700</td></tr>
<tr><td colspan="2">Primary part mass standard encapsulation</td><td>$m_{PS}$</td><td>kg</td><td>4.7</td><td colspan="3">6.1</td></tr>
<tr><td colspan="2">Primary part mass thermal encapsulation</td><td>$m_{PT}$</td><td>kg</td><td>6.1</td><td colspan="3">8.1</td></tr>
<tr><td colspan="2">Secundary part mass</td><td>$m_S$</td><td>kg/m</td><td colspan="4">5.4</td></tr>
<tr><td colspan="2">Necessary coolant flow $\Delta\vartheta_N$ [10)]</td><td>$Q_{min}$</td><td>l/min</td><td>0.57</td><td colspan="3">0.79</td></tr>
<tr><td rowspan="2">Constant to determine the pressure loss [7)]</td><td>Standard encapsulation</td><td rowspan="2">$k_{dp}$</td><td></td><td>0.16</td><td colspan="3">0.16</td></tr>
<tr><td>Thermal encapsulation</td><td></td><td>0.16</td><td colspan="3">0.16</td></tr>
<tr><td rowspan="2">Pressure loss at $Q_N$</td><td>Standard encapsulation</td><td rowspan="2">Δp</td><td rowspan="2">bar</td><td>0.06</td><td colspan="3">0.10</td></tr>
<tr><td>Thermal encapsulation</td><td>0.06</td><td colspan="3">0.11</td></tr>
<tr><td colspan="2">Permissible coolant inlet pressure</td><td>$p_{max}$</td><td>bar</td><td colspan="4">10</td></tr>
<tr><td colspan="2">Coolant inlet temperature [8)]</td><td>$\vartheta_{in}$</td><td>°C</td><td colspan="4">+15 ... +40</td></tr>
<tr><td colspan="2">Temperature rise at $P_{vN}$ [9)]</td><td>$\Delta\vartheta_N$</td><td>K</td><td colspan="4">10</td></tr>
<tr><td colspan="2">Thermal time constant</td><td>$T_{th}$</td><td>min</td><td colspan="4">6</td></tr>
<tr><td colspan="2">Permitted secondary part temperature</td><td>$T_{Smax}$</td><td>°C</td><td colspan="4">70</td></tr>
<tr><td colspan="2">Admissible ambient temperature during Operation</td><td>$T_{amb}$</td><td>°C</td><td colspan="4">0 ... +40</td></tr>
<tr><td colspan="2">Perm. storage and transport temperature</td><td>$T_L$</td><td>°C</td><td colspan="4">-20 ... +60</td></tr>
<tr><td colspan="2">Degree of protection</td><td></td><td></td><td colspan="4">IP65</td></tr>
<tr><td colspan="2">Insulation class according to DIN VDE 0530-1</td><td></td><td></td><td colspan="4">F</td></tr>
</table>

1) The determined values are root-mean-square according to IEC 60034-1, if no others are specified. Reference value 540 $V_{DC}$.

2) The maximum reachable force depends on the drive control device used.

3) The reachable velocities depend on the supply voltage.

4) EMF = electromagnetic force. Effective value referring to 1 m/s.

5) Please note the information on the power wire cross section in "Necessary Power Wire Cross-Section" on page 20.

6) Between primary and secondary part at nominal air gap, primary part currentless.

7) Coolant water. To determine the pressure drop depending on the coolant flow see chapter 9.6 "Motor Cooling System" on page 116.

8) The coolant inlet temperature should be max. 5°C lower than the existing ambient temperature (danger of condensation!).

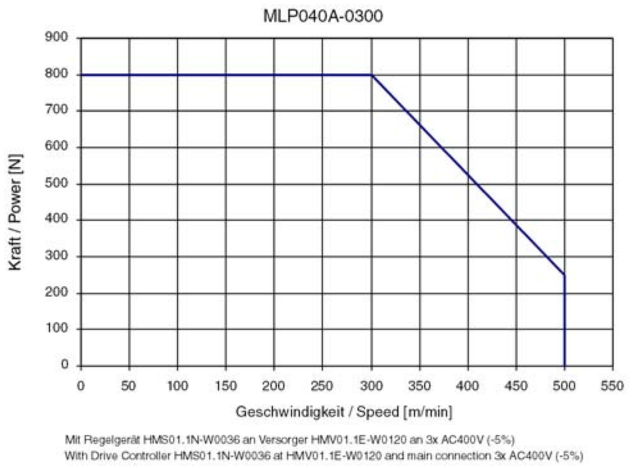
9) Operation with liquid cooling, coolant water, coolant inlet temperature 30°C.

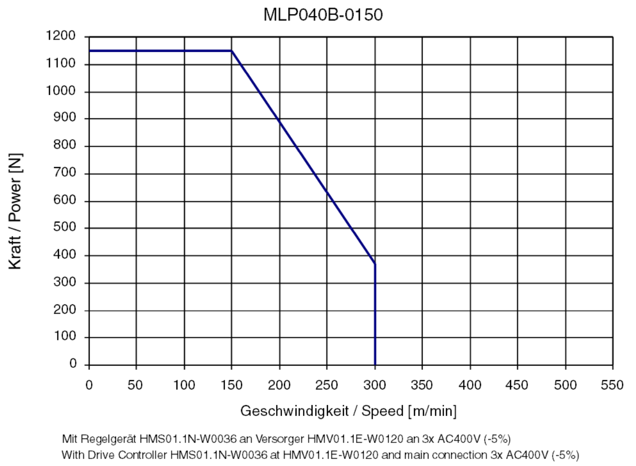
10) For further notes regarding flow rate, refer to chapter 9.6 "Motor Cooling System" on page 116.

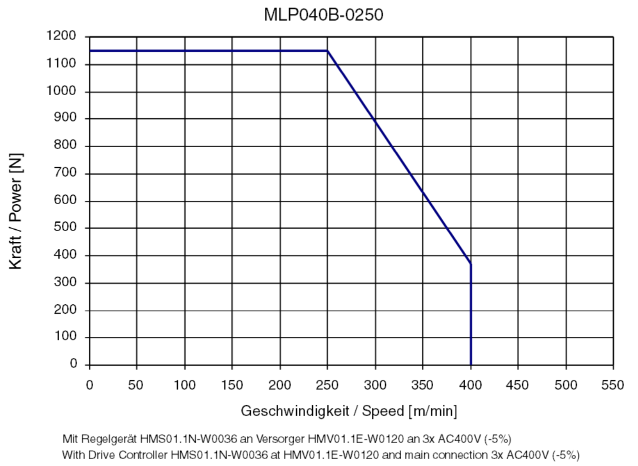
i. p. = in preparation.

*Fig.4-6: Data sheet frame size MLP040*

**Motor Characteristic Curves Frame Size 040**



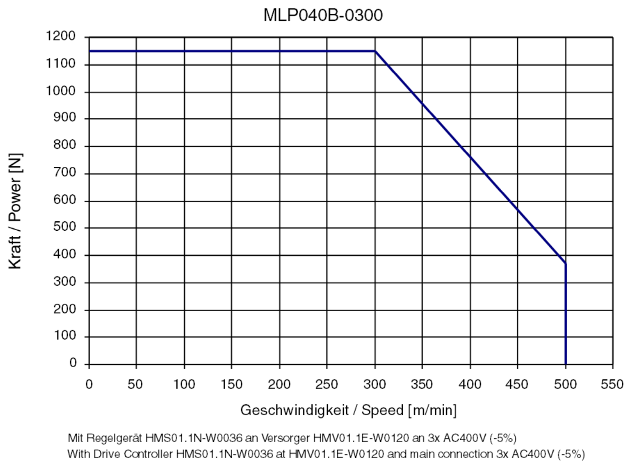




*Fig.4-7: Motor Characteristic Curves Frame Size 040*

# 4.3 Technical Data - Frame Size MLP070

## 4.3.1 Frame Size MLP070A

| Description | | Symbol | Unit | MLP070A | | |
|---|---|---|---|---|---|---|
| **Motor data** [1] | | | | | | |
| Winding code | | | | 0150 | 0220 | 0300 |
| Appropriate secondary parts | | | | MLS070S-3A-****-NNNN | | |
| Maximum force [2] | | $F_{max}$ | N | 2,000 | | |
| Continuous nominal force | | $F_{dN}$ | N | 550 | | |
| Maximum current | | $I_{max}$ | A | 36 | 42 | 55 |
| Continuous nominal voltage | | $I_{dN}$ | A | 5.5 | 6.3 | 10.5 |
| Maximum velocity at $F_{max}$ [3] | | $v_{Fmax}$ | m/min | 150 | 220 | 300 |
| Nominal velocity [3] | | $v_N$ | m/min | 200 | 360 | 450 |
| Force constant | | $K_{iFN}$ | N/A | 100 | 87 | 52 |
| Voltage constant [4] | | $K_{EMF}$ | Vs/m | 79.5 | 47 | 20 |
| Winding resistance at 20°C | | $R_{12}$ | ohms | 9 | 3.3 | 2.9 |
| Winding inductivity | | $L_{12}$ | mH | 51 | 25.7 | 15 |
| Minimum cross-section connection cable [5] | | $A_{PL}$ | mm² | 1.5 | | |
| Rated power loss | | $P_{vN}$ | W | 780 | | |
| Nominal air gap | | δ | mm | $1.0^{+0.55}_{-0.4}$ | | |
| Pole width | | $T_p$ | mm | 37.5 | | |
| Attractive force [6] | | $F_{ATT}$ | N | 2,900 | | |
| Primary part mass standard encapsulation | | $m_{PS}$ | kg | 8.4 | | |
| Primary part mass thermal encapsulation | | $m_{PT}$ | kg | 10.9 | | |
| Secundary part mass | | $m_S$ | kg/m | 9.4 | | |
| Necessary coolant flow $\Delta\vartheta_N$ [10] | | $Q_{min}$ | l/min | 1.12 | | |
| Constant to determine the pressure loss [7] | Standard encapsulation | $k_{dp}$ | | 0.18 | | |
| | Thermal encapsulation | | | 0.18 | | |
| Pressure loss at $Q_N$ | Standard encapsulation | Δp | bar | 0.22 | | |
| | Thermal encapsulation | | | 0.22 | | |
| Permissible coolant inlet pressure | | $p_{max}$ | bar | 10 | | |
| Coolant inlet temperature [8] | | $\vartheta_{in}$ | °C | +15 ... +40 | | |
| Temperature rise at $P_{vN}$ [9] | | $\Delta\vartheta_N$ | K | 10 | | |
| Thermal time constant | | $T_{th}$ | min | 6 | | |
| Permitted secondary part temperature | | $T_{Smax}$ | °C | 70 | | |
| Admissible ambient temperature during operation | | $T_{amb}$ | °C | 0 ... +40 | | |
| Perm. storage and transport temperature | | $T_L$ | °C | -20 ... +60 | | |
| Degree of protection | | | | IP65 | | |

| Description | Symbol | Unit | MLP070A |
|---|---|---|---|
| Insulation class according to DIN VDE 0530-1 | | | F |

1) The determined values are root-mean-square according to IEC 60034-1, if no others are specified. Reference value 540 $V_{DC}$.

2) The maximum reachable force depends on the drive control device used.

3) The reachable velocities depend on the supply voltage.

4) EMF = electromagnetic force. Effective value referring to 1 m/s.

5) Please note the information on the power wire cross section in "Necessary Power Wire Cross-Section" on page 20.

6) Between primary and secondary part at nominal air gap, primary part currentless.

7) Coolant water. To determine the pressure drop depending on the coolant flow see chapter 9.6 "Motor Cooling System" on page 116.

8) The coolant inlet temperature should be max. 5°C lower than the existing ambient temperature (danger of condensation!).

9) Operation with liquid cooling, coolant water, coolant inlet temperature 30°C.

10) For further notes regarding flow rate, refer to chapter 9.6 "Motor Cooling System" on page 116.

*Fig.4-8: Data sheet frame size MLP070A*

**Motor Characteristic Curves Frame Size 070A**

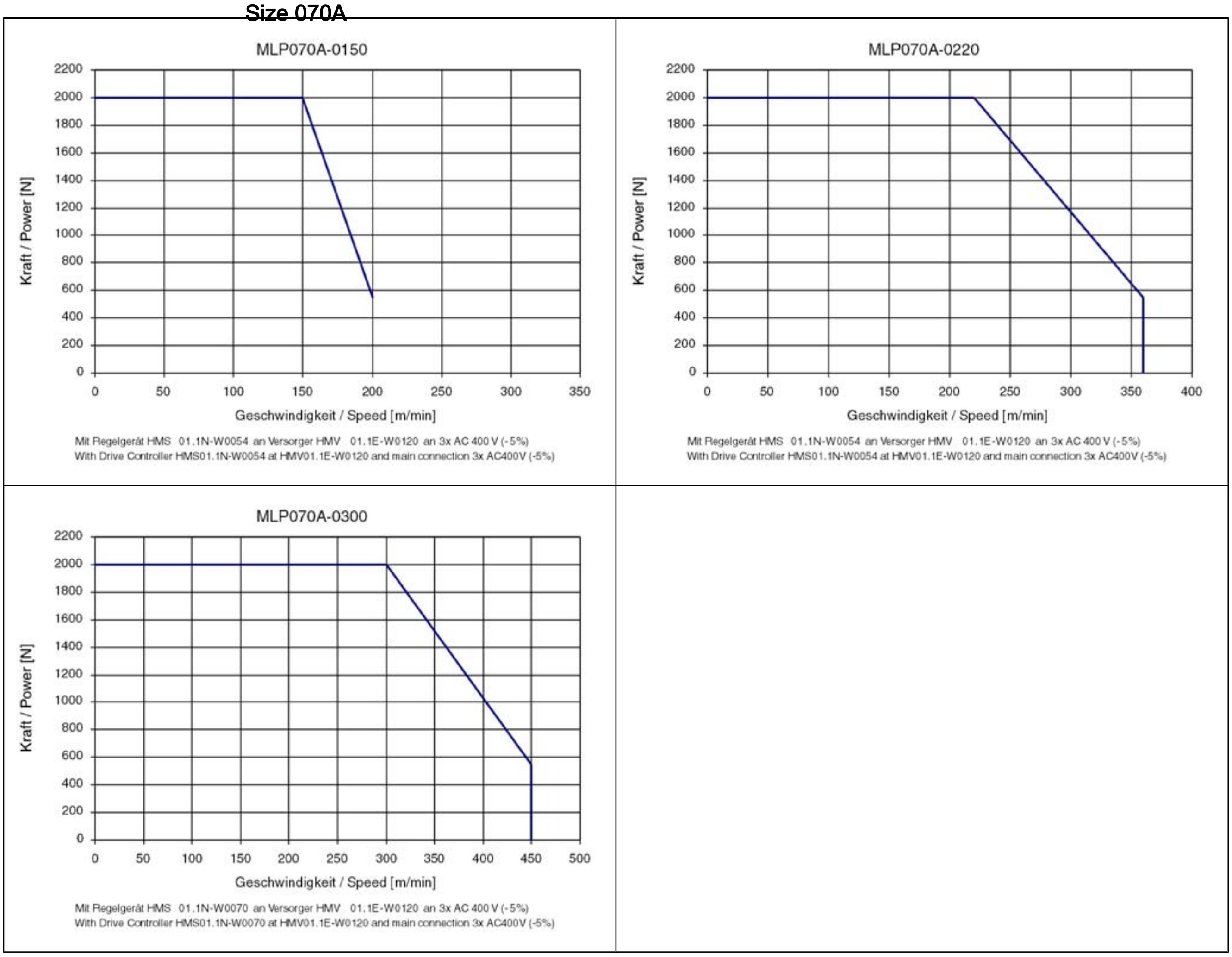



*Fig.4-9: Motor Characteristic Curves Frame Size 070A*

Technical Data IndraDyn L

## 4.3.2 Frame Size MLP070B

| Description | | Symbol | Unit | MLP070B | | | | |
|---|---|---|---|---|---|---|---|---|
| **Motor data** [1) ] | | | | | | | | |
| Winding code | | | | 0100 | 0120 | 0150 | 0250 | 0300 |
| Appropriate secondary parts | | | | MLS070S-3A-****-NNNN | | | | |
| Maximum force [2)] | | $F_{max}$ | N | 2,600 | | | | |
| Continuous nominal force | | $F_{dN}$ | N | 820 | | | | |
| Maximum current | | $I_{max}$ | A | 28 | 42 | 48 | 55 | 70 |
| Continuous nominal voltage | | $I_{dN}$ | A | 5.5 | 5.8 | 6.2 | 10 | 12 |
| Maximum velocity at $F_{max}$ [3)] | | $v_{Fmax}$ | m/min | 100 | 120 | 150 | 250 | 300 |
| Nominal velocity [3)] | | $v_N$ | m/min | 200 | 220 | 260 | 400 | 450 |
| Force constant | | $K_{iFN}$ | N/A | 149 | 141 | 132 | 82 | 68 |
| Voltage constant [4)] | | $K_{EMF}$ | Vs/m | 85 | 80 | 65 | 43 | 60 |
| Winding resistance at 20°C | | $R_{12}$ | ohms | 15.1 | 9.2 | 6.1 | 3 | 2.4 |
| Winding inductivity | | $L_{12}$ | mH | 90 | 55 | 38 | 17 | 13 |
| Minimum cross-section connection cable [5)] | | $A_{PL}$ | mm² | 1.5 | | | | |
| Rated power loss | | $P_{vN}$ | W | 900 | | | | |
| Nominal air gap | | δ | mm | $1.0^{+0.55}_{-0.4}$ | | | | |
| Pole width | | $T_p$ | mm | 37.5 | | | | |
| Attractive force [6)] | | $F_{ATT}$ | N | 3,750 | | | | |
| Primary part mass standard encapsulation | | $m_{PS}$ | kg | 10.4 | | | | |
| Primary part mass thermal encapsulation | | $m_{PT}$ | kg | 13.4 | | | | |
| Secundary part mass | | $m_S$ | kg/m | 9.4 | | | | |
| Necessary coolant flow $\Delta\vartheta_N$ [10)] | | $Q_{min}$ | l/min | 1.29 | | | | |
| Constant to Determine the Pressure Loss [7)] | Standard encap-sulation | $k_{dp}$ | | 0.18 | | | | |
| | Thermal encapsu-lation | | | 0.18 | | | | |
| Pressure loss at $Q_N$ | Standard encap-sulation | Δp | bar | 0.28 | | | | |
| | Thermal encapsu-lation | | | 0.29 | | | | |
| Permissible coolant inlet pressure | | $p_{max}$ | bar | 10 | | | | |
| Coolant inlet temperature [8)] | | $\vartheta_{in}$ | °C | +15 ... +40 | | | | |
| Temperature rise at $P_{vN}$ [9)] | | $\Delta\vartheta_N$ | K | 10 | | | | |
| Thermal time constant | | $T_{th}$ | min | 5.7 | | | | |
| Permitted secondary part temperature | | $T_{Smax}$ | °C | 70 | | | | |
| Admissible ambient temperature during operation | | $T_{amb}$ | °C | 0 ... +40 | | | | |
| Perm. storage and transport temperature | | $T_L$ | °C | -20 ... +60 | | | | |
| Degree of protection | | | | IP65 | | | | |

| Description | Symbol | Unit | MLP070B |
|---|---|---|---|
| Insulation class according to DIN VDE 0530-1 | | | F |

1) The determined values are root-mean-square according to IEC 60034-1, if no others are specified. Reference value 540 $V_{DC}$.

2) The maximum reachable force depends on the drive control device used.

3) The reachable velocities depend on the supply voltage.

4) EMF = electromagnetic force. Effective value referring to 1 m/s.

5) Rated according to EN60204-1 (1993), installation mode B2 and conversion factor for Bosch Rexroth cables at an ambient temperature of 40°C. When using other cables, larger cross sections may be necessary. For further notes regarding connection and power cables see chapter 8.1.1 "Power Cable on the Primary Part" on page 87.

6) Between primary and secondary part at nominal air gap, primary part currentless.

7) Coolant water. To determine the pressure drop depending on the coolant flow see chapter 9.6 "Motor Cooling System" on page 116.

8) The coolant inlet temperature should be max. 5°C lower than the existing ambient temperature (danger of condensation!).

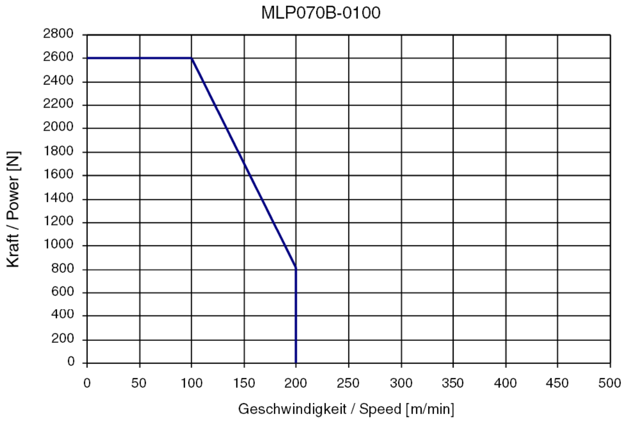
9) Operation with liquid cooling, coolant water, coolant inlet temperature 30°C.

10) For further notes regarding flow rate, refer to chapter 9.6 "Motor Cooling System" on page 116.

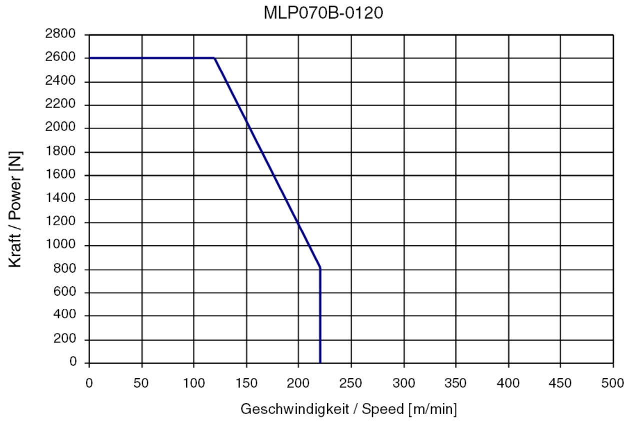
*Fig.4-10: Data sheet frame size MLP070B*

**Motor Characteristic Curves Frame Size 070B**

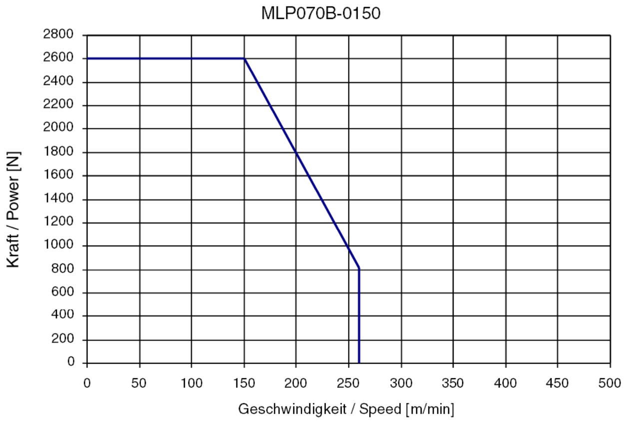
Technical Data IndraDyn L



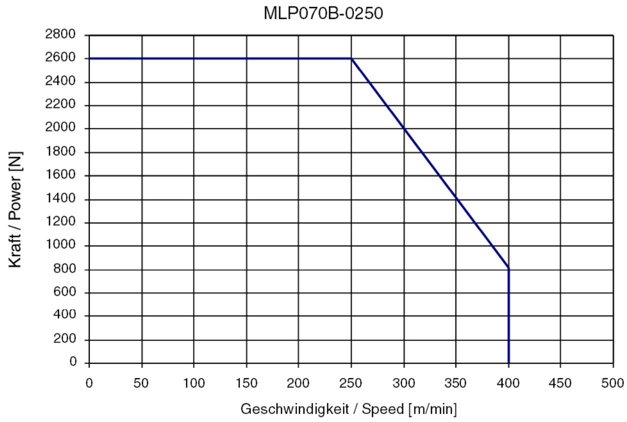

Mit Regelgerät HMS 01.1N-W0036 an Versorger HMV 01.1E-W0120 an 3x AC 400 V (-5%)
With Drive Controller HMS01.1N-W0036 at HMV01.1E-W0120 and main connection 3x AC400V (-5%)



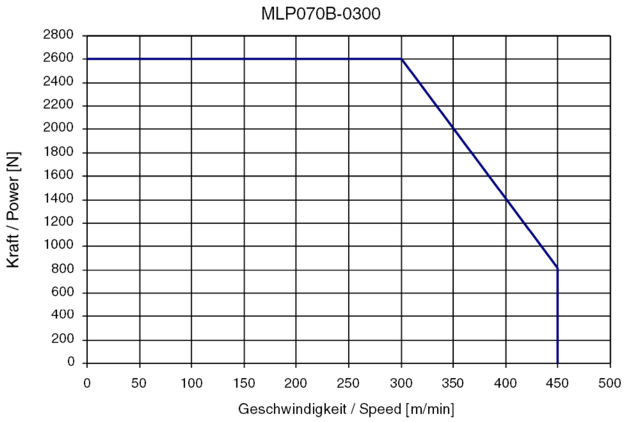

Mit Regelgerät HMS 01.1N-W0054 an Versorger HMV 01.1E-W0120 an 3x AC 400 V (-5%)
With Drive Controller HMS01.1N-W0054 at HMV01.1E-W0120 and main connection 3x AC400V (-5%)




Mit Regelgerät HMS 01.1N-W0054 an Versorger HMV 01.1E-W0120 an 3x AC 400 V (-5%)
With Drive Controller HMS01.1N-W0054 at HMV01.1E-W0120 and main connection 3x AC400V (-5%)




Mit Regelgerät HMS 01.1N-W0070 an Versorger HMV 01.1E-W0120 an 3x AC 400 V (-5%)
With Drive Controller HMS01.1N-W0070 at HMV01.1E-W0120 and main connection 3x AC400V (-5%)




Mit Regelgerät HMS 01.1N-W0150 an Versorger HMV 01.1E-W0120 an 3x AC 400 V (-5%)
With Drive Controller HMS01.1N-W0150 at HMV01.1E-W0120 and main connection 3x AC400V (-5%)

*Fig.4-11: Motor Characteristic Curves Frame Size 070B*

## 4.3.3 Frame Size MLP070C

| Description | | Symbol | Unit | MLP070C | | | |
|---|---|---|---|---|---|---|---|
| **Motor data** [1] | | | | | | | |
| Winding code | | | | 0120 | 0150 | 0240 | 0300 |
| Appropriate secondary parts | | | | MLS070S-3A-****-NNNN | | | |
| Maximum force [2] | | $F_{max}$ | N | 3,800 | | | |
| Continuous nominal force | | $F_{dN}$ | N | 1,200 | | | |
| Maximum current | | $I_{max}$ | A | 55 | 70 | 90 | 110 |
| Continuous nominal voltage | | $I_{dN}$ | A | 8.9 | 11.7 | 13 | 19 |
| Maximum velocity at $F_{max}$ [3] | | $v_{Fmax}$ | m/min | 120 | 150 | 240 | 300 |
| Nominal velocity [3] | | $v_N$ | m/min | 180 | 250 | 350 | 450 |
| Force constant | | $K_{iFN}$ | N/A | 135 | 98.3 | 92 | 63 |
| Voltage constant [4] | | $K_{EMF}$ | Vs/m | 78 | 91 | 49 | 38 |
| Winding resistance at 20°C | | $R_{12}$ | ohms | 5.7 | 4.1 | 2 | 1.5 |
| Winding inductivity | | $L_{12}$ | mH | 36 | 22 | 11 | 7.5 |
| Minimum cross-section connection cable [5] | | $A_{PL}$ | mm² | 1.5 | | | 2.5 |
| Rated power loss | | $P_{vN}$ | W | 1,100 | | | |
| Nominal air gap | | δ | mm | $1.0^{+0.55}_{-0.4}$ | | | |
| Pole width | | $T_p$ | mm | 37.5 | | | |
| Attractive force [6] | | $F_{ATT}$ | N | 5,500 | | | |
| Primary part mass standard encapsulation | | $m_{PS}$ | kg | 14.3 | | | |
| Primary part mass thermal encapsulation | | $m_{PT}$ | kg | 18.4 | | | |
| Secundary part mass | | $m_S$ | kg/m | 9.4 | | | |
| Necessary coolant flow $\Delta\vartheta_N$ [10] | | $Q_{min}$ | l/min | 1.58 | | | |
| Constant to determine the pressure loss [7] | Standard encapsulation | $k_{dp}$ | | 0.19 | | | |
| | Thermal encapsulation | | | 0.19 | | | |
| Pressure loss at $Q_N$ | Standard encapsulation | $\Delta p$ | bar | 0.43 | | | |
| | Thermal encapsulation | | | 0.43 | | | |
| Permissible coolant inlet pressure | | $p_{max}$ | bar | 10 | | | |
| Coolant inlet temperature [8] | | $\vartheta_{in}$ | °C | +15 ... +40 | | | |
| Temperature rise at $P_{vN}$ [9] | | $\Delta\vartheta_N$ | K | 10 | | | |
| Thermal time constant | | $T_{th}$ | min | 6.6 | | | |
| Permitted secondary part temperature | | $T_{Smax}$ | °C | 70 | | | |
| Admissible ambient temperature during operation | | $T_{amb}$ | °C | 0 ... +40 | | | |
| Perm. storage and transport temperature | | $T_L$ | °C | -20 ... +60 | | | |
| Degree of protection | | | | IP65 | | | |

Technical Data IndraDyn L

| Description | Symbol | Unit | MLP070C |
|---|---|---|---|
| Insulation class according to DIN VDE 0530-1 | | | F |

1) The determined values are root-mean-square according to IEC 60034-1, if no others are specified. Reference value 540 $V_{DC}$.

2) The maximum reachable force depends on the drive control device used.

3) The reachable velocities depend on the supply voltage.

4) EMF = electromagnetic force. Effective value referring to 1 m/s.

5) Please note the information on the power wire cross section in "Necessary Power Wire Cross-Section" on page 20.

6) Between primary and secondary part at nominal air gap, primary part currentless.

7) Coolant water. To determine the pressure drop depending on the coolant flow see chapter 9.6 "Motor Cooling System" on page 116.

8) The coolant inlet temperature should be max. 5°C lower than the existing ambient temperature (danger of condensation!).

9) Operation with liquid cooling, coolant water, coolant inlet temperature 30°C.

10) For further notes regarding flow rate, refer to chapter 9.6 "Motor Cooling System" on page 116.

*Fig.4-12: Data sheet frame size MLP070C*

**Motor Characteristic Curves Frame Size 070C**

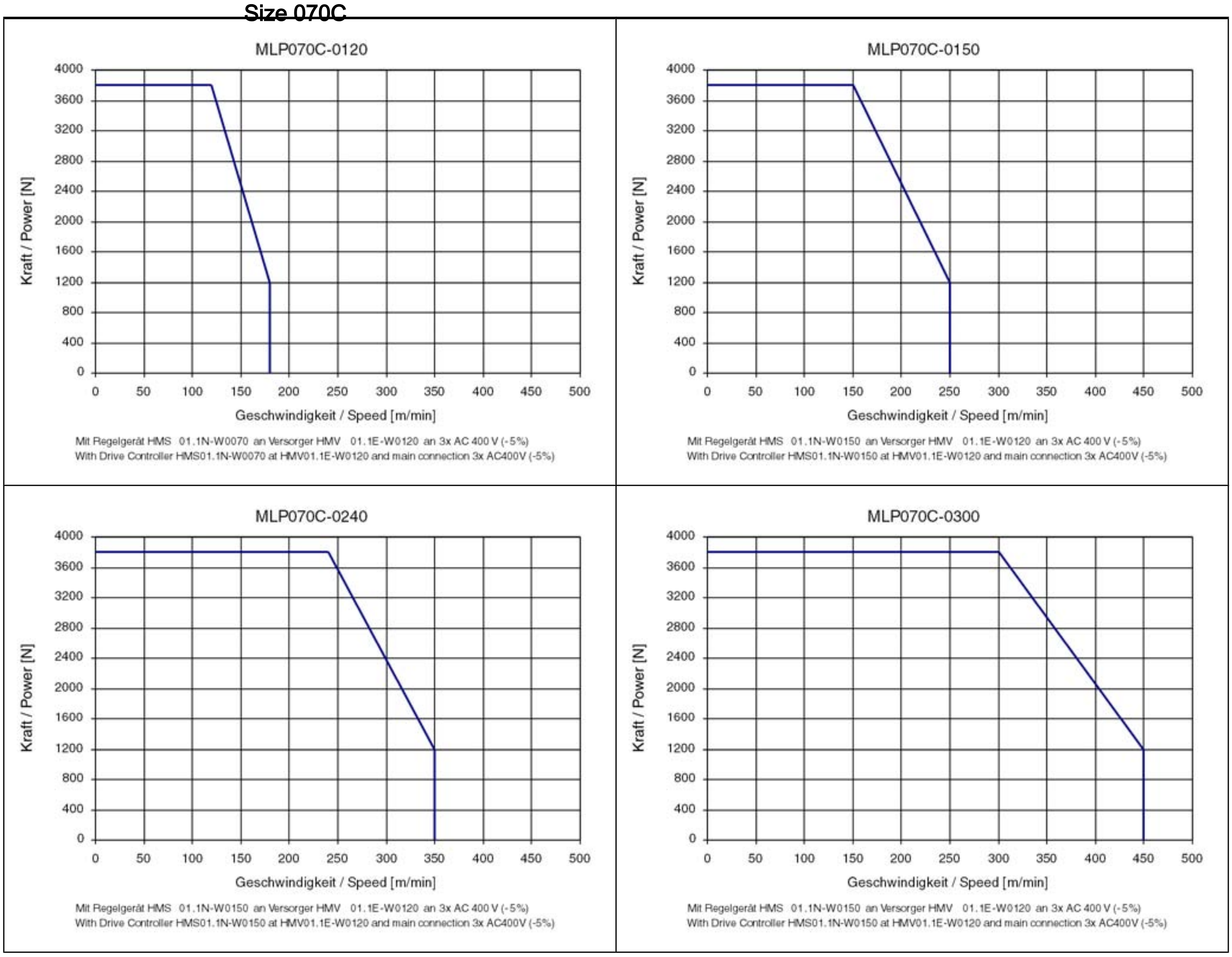



*Fig.4-13: Motor Characteristic Curves Frame Size 070C*

# 4.4 Technical Data - Frame Size MLP100

## 4.4.1 Frame Size MLP100A

| Description | Symbol | Unit | MLP100A | | | |
|---|---|---|---|---|---|---|
| **Motor data** [1] | | | | | | |
| Winding code | | | 0090 | 0120 | 0150 | 0190 |
| Appropriate secondary parts | | | MLS100S-3A-****-NNNN | | | |
| Maximum force [2] | $F_{max}$ | N | 3,750 | | | |
| Continuous nominal force | $F_{dN}$ | N | 1,180 | | | |
| Maximum current | $I_{max}$ | A | 38 | 44 | 55 | 70 |
| Continuous nominal voltage | $I_{dN}$ | A | 6.6 | 8 | 10 | 12 |
| Maximum velocity at $F_{max}$ [3] | $v_{Fmax}$ | m/min | 90 | 120 | 150 | 190 |
| Nominal velocity [3] | $v_N$ | m/min | 150 | 190 | 220 | 290 |
| Force constant | $K_{iFN}$ | N/A | 186 | 148 | 118 | 98 |
| Voltage constant [4] | $K_{EMF}$ | Vs/m | 162 | 89 | 77 | 59 |
| Winding resistance at 20°C | $R_{12}$ | ohms | 12.2 | 7.8 | 6.9 | 3.2 |
| Winding inductivity | $L_{12}$ | mH | 70 | 42 | 31 | 16 |
| Minimum cross-section connection cable [5] | $A_{PL}$ | mm² | 1.5 | | | |
| Rated power loss | $P_{vN}$ | W | 1,500 | | | |
| Nominal air gap | δ | mm | $1.0^{+0.55}_{-0.4}$ | | | |
| Pole width | $\tau_p$ | mm | 37.5 | | | |
| Attractive force [6] | $F_{ATT}$ | N | 5,400 | | | |
| Primary part mass standard encapsulation | $m_{PS}$ | kg | 13.5 | | | |
| Primary part mass thermal encapsulation | $m_{PT}$ | kg | 17 | | | |
| Secundary part mass | $m_S$ | kg/m | 13.4 | | | |
| Necessary coolant flow $\Delta\vartheta_N$ [10] | $Q_{min}$ | l/min | 2 | | | |
| Constant to Determine the Pressure Loss [7] – Standard encapsulation | $k_{dp}$ | | 0.19 | | | |
| Constant to Determine the Pressure Loss [7] – Thermal encapsulation | $k_{dp}$ | | 0.19 | | | |
| Pressure loss at $Q_N$ – Standard encapsulation | Δp | bar | 0.29 | | | |
| Pressure loss at $Q_N$ – Thermal encapsulation | Δp | bar | 0.3 | | | |
| Permissible coolant inlet pressure | $p_{max}$ | bar | 10 | | | |
| Coolant inlet temperature [8] | $\vartheta_{in}$ | °C | +15 ... +40 | | | |
| Temperature rise at $P_{vN}$ [9] | $\Delta\vartheta_N$ | K | 10 | | | |
| Thermal time constant | $T_{th}$ | min | 6.4 | | | |
| Permitted secondary part temperature | $T_{Smax}$ | °C | 70 | | | |
| Admissible ambient temperature during operation | $T_{amb}$ | °C | 0 ... +40 | | | |
| Perm. storage and transport temperature | $T_L$ | °C | -20 ... +60 | | | |
| Degree of protection | | | IP65 | | | |

Technical Data IndraDyn L

| Description | Symbol | Unit | MLP100A |
|---|---|---|---|
| Insulation class according to DIN VDE 0530-1 | | | F |
| 1) The determined values are root-mean-square according to IEC 60034-1, if no others are specified. Reference value 540 $V_{DC}$. | | | |
| 2) The maximum reachable force depends on the drive control device used. | | | |
| 3) The reachable velocities depend on the supply voltage. | | | |
| 4) EMF = electromagnetic force. Effective value referring to 1 m/s. | | | |
| 5) Please note the information on the power wire cross section in "Necessary Power Wire Cross-Section" on page 20. | | | |
| 6) Between primary and secondary part at nominal air gap, primary part currentless. | | | |
| 7) Coolant water. To determine the pressure drop depending on the coolant flow see chapter 9.6 "Motor Cooling System" on page 116. | | | |
| 8) The coolant inlet temperature should be max. 5°C lower than the existing ambient temperature (danger of condensation!). | | | |
| 9) Operation with liquid cooling, coolant water, coolant inlet temperature 30°C. | | | |
| 10) For further notes regarding flow rate, refer to chapter 9.6 "Motor Cooling System" on page 116. | | | |

*Fig.4-14: Data sheet frame size MLP100A*

**Motor Characteristic Curves Frame Size 100A**

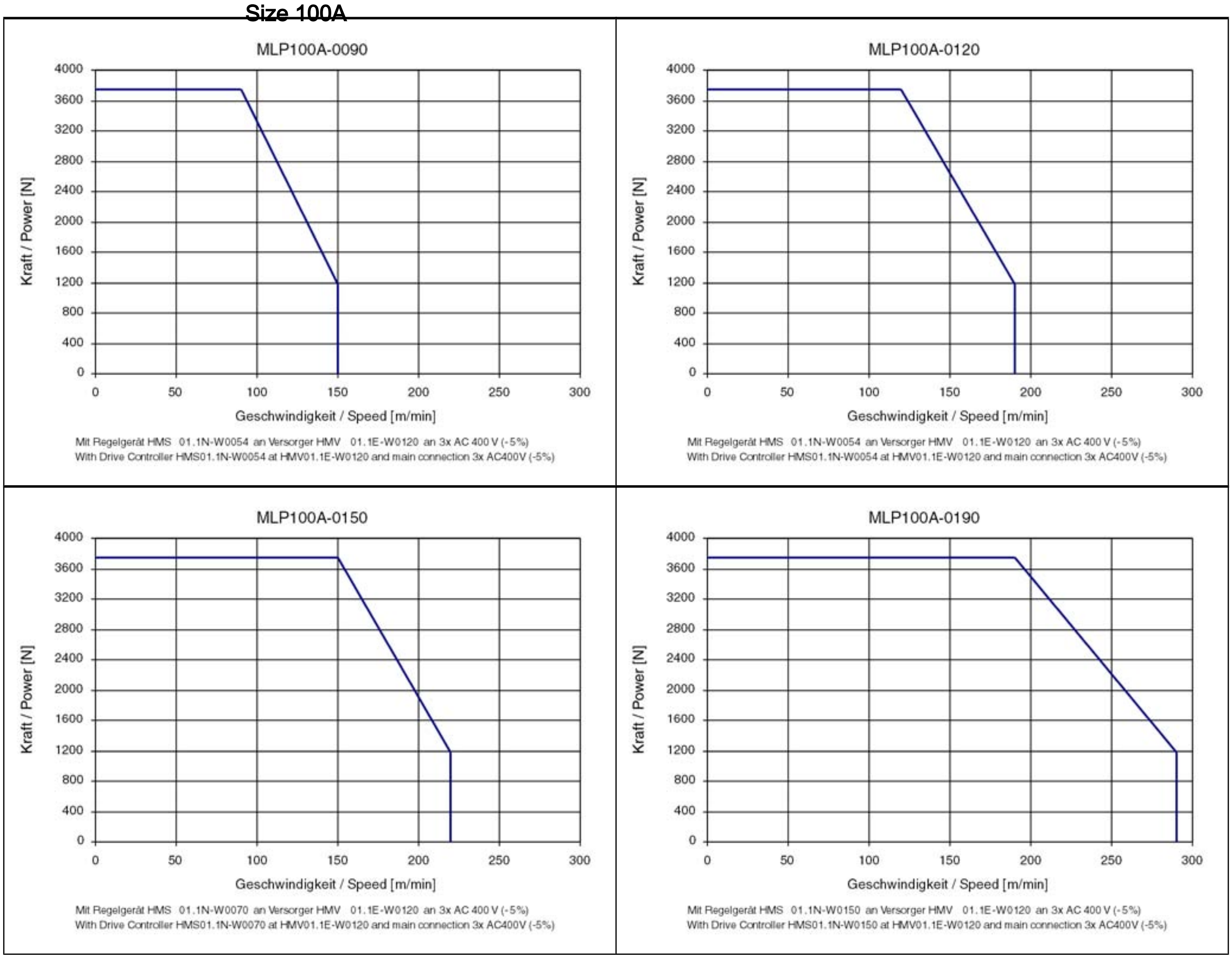



*Fig.4-15: Motor Characteristic Curves Frame Size 100A*

## 4.4.2 Frame Sizes MLP100B, MLP100C

| Description | Symbol | Unit | MLP100 | | | | |
|---|---|---|---|---|---|---|---|
| **Motor data** 1) | | | | | | | |
| Frame length | | | B | | C | | |
| Winding code | | | 0120 | 0250 | 0090 | 0120 | 0190 |
| Appropriate secondary parts | | | MLS100S-3A-****-NNNN | | | | |
| Maximum force 2) | $F_{max}$ | N | 5,600 | | 7,150 | | |
| Continuous nominal force | $F_{dN}$ | N | 1,785 | | 2,310 | | |
| Maximum current | $I_{max}$ | A | 70 | 130 | 90 | 85 | 140 |
| Continuous nominal voltage | $I_{dN}$ | A | 12 | 22 | 13 | 15 | 23 |
| Maximum velocity at $F_{max}$ 3) | $v_{Fmax}$ | m/min | 120 | 250 | 90 | 120 | 190 |
| Nominal velocity 3) | $v_N$ | m/min | 190 | 350 | 170 | 190 | 290 |
| Force constant | $K_{iFN}$ | N/A | 149 | 81 | 178 | 154 | 100 |
| Voltage constant 4) | $K_{EMF}$ | Vs/m | 87 | 49 | 100 | 89 | 59 |
| Winding resistance at 20°C | $R_{12}$ | ohms | 4.5 | 2 | 6 | 3.9 | 1.5 |
| Winding inductivity | $L_{12}$ | mH | 25 | 9 | 38 | 22 | 8 |
| Minimum cross-section connection cable 5) | $A_{PL}$ | mm² | 1.5 | 2.5 | 1.5 | 1.5 | 4 |
| Rated power loss | $P_{vN}$ | W | 1,300 | | 1,600 | | |
| Nominal air gap | δ | mm | $1.0^{+0.55}_{-0.4}$ | | | | |
| Pole width | $T_p$ | mm | 37.5 | | | | |
| Attractive force 6) | $F_{ATT}$ | N | 8,000 | | 10,400 | | |
| Primary part mass standard encapsulation | $m_{PS}$ | kg | 18.7 | | 24 | | |
| Primary part mass thermal encapsulation | $m_{PT}$ | kg | 23.3 | | 29.7 | | |
| Secundary part mass | $m_S$ | kg/m | 13.4 | | | | |
| Necessary coolant flow $\Delta\vartheta_N$ 10) | $Q_{min}$ | l/min | 1.87 | | 2.3 | | |
| Constant to Determine the Pressure Loss 7) – Standard encapsulation | $k_{dp}$ | | 0.18 | | 0.19 | | |
| Constant to Determine the Pressure Loss 7) – Thermal encapsulation | $k_{dp}$ | | 0.18 | | 0.19 | | |
| Pressure loss at $Q_N$ – Standard encapsulation | Δp | bar | 0.52 | | 0.8 | | |
| Pressure loss at $Q_N$ – Thermal encapsulation | Δp | bar | 0.54 | | 0.82 | | |
| Permissible coolant inlet pressure | $p_{max}$ | bar | 10 | | | | |
| Coolant inlet temperature 8) | $\vartheta_{in}$ | °C | +15 ... +40 | | | | |
| Temperature rise at $P_{vN}$ 9) | $\Delta\vartheta_N$ | K | 10 | | | | |
| Thermal time constant | $T_{th}$ | min | 7 | | 6 | | |
| Permitted secondary part temperature | $T_{Smax}$ | °C | 70 | | | | |
| Admissible ambient temperature during operation | $T_{amb}$ | °C | 0 ... +40 | | | | |
| Perm. storage and transport temperature | $T_L$ | °C | -20 ... +60 | | | | |
| Degree of protection | | | IP65 | | | | |

| Description | Symbol | Unit | MLP100 |
|---|---|---|---|
| Insulation class according to DIN VDE 0530-1 | | | F |

1) The determined values are root-mean-square according to IEC 60034-1, if no others are specified. Reference value 540 $V_{DC}$.

2) The maximum reachable force depends on the drive control device used.

3) The reachable velocities depend on the supply voltage.

4) EMF = electromagnetic force. Effective value referring to 1 m/s.

5) Please note the information on the power wire cross section in "Necessary Power Wire Cross-Section" on page 20.

6) Between primary and secondary part at nominal air gap, primary part currentless.

7) Coolant water. To determine the pressure drop depending on the coolant flow see chapter 9.6 "Motor Cooling System" on page 116.

8) The coolant inlet temperature should be max. 5°C lower than the existing ambient temperature (danger of condensation!).

9) Operation with liquid cooling, coolant water, coolant inlet temperature 30°C.

10) For further notes regarding flow rate, refer to chapter 9.6 "Motor Cooling System" on page 116.

*Fig.4-16: Data Sheet Frame Size MLP100B, MLP100C*

**Motor Characteristic Curves Frame Size 100B, 100C**

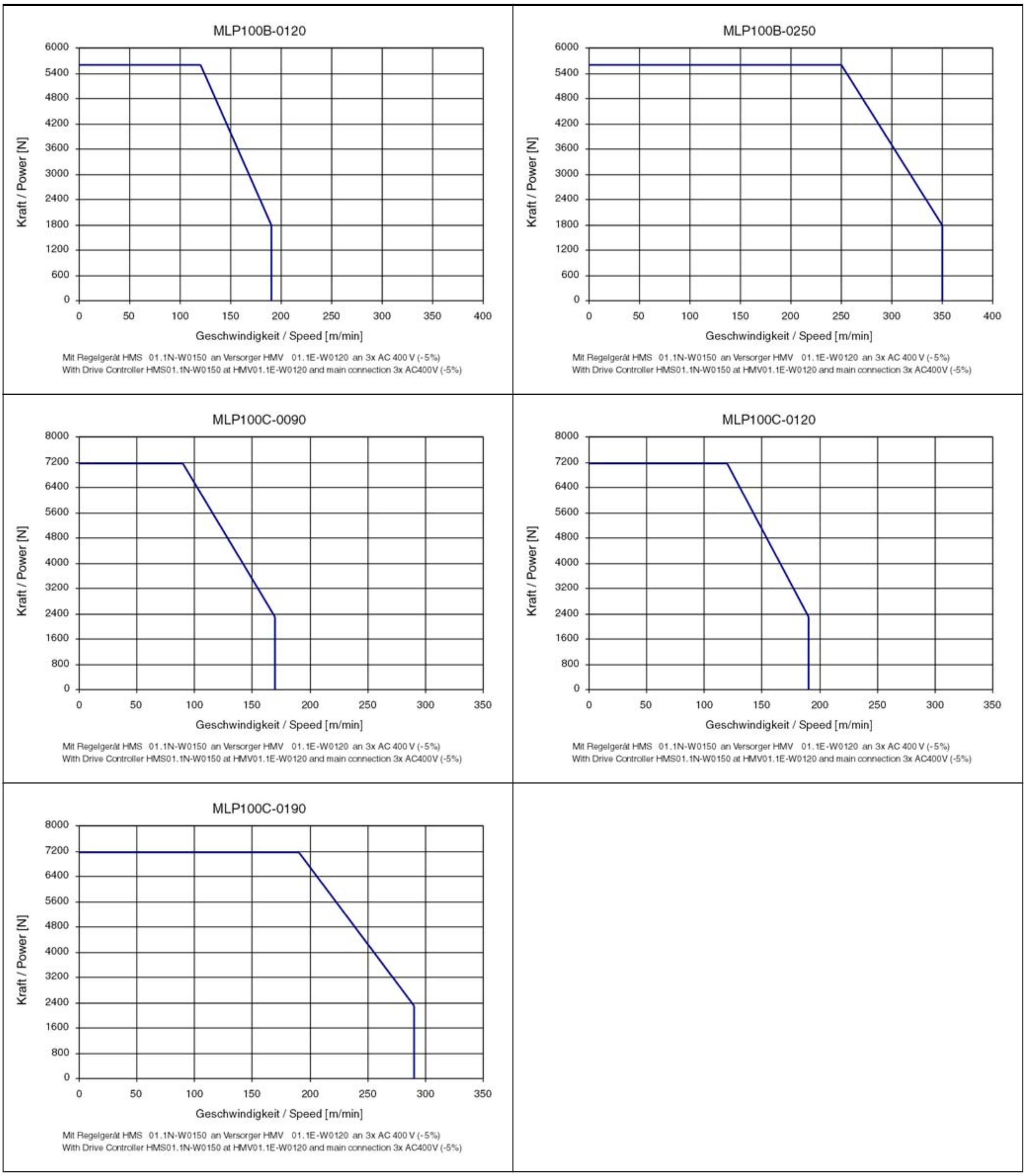



*Fig.4-17: Motor Characteristic Curves Frame Size 100B, 100C*

Technical Data IndraDyn L

# 4.5 Technical Data - Frame Size MLP140

## 4.5.1 Frame Sizes MLP140A, MLP140B

| **Description** | | **Symbol** | **Unit** | **MLP140** | | |
|---|---|---|---|---|---|---|
| **Motor data** [1] | | | | | | |
| Frame length | | | | A | B | |
| Winding code | | | | 0120 | 0090 | 0120 |
| Appropriate secondary parts | | | | MLS140S-3A-****-NNNN | | |
| Maximum force [2] | | $F_{max}$ | N | 5,200 | 7,650 | |
| Continuous nominal force | | $F_{dN}$ | N | 1,680 | 2,415 | |
| Maximum current | | $I_{max}$ | A | 70 | 85 | 105 |
| Continuous nominal voltage | | $I_{dN}$ | A | 12 | 15 | 18 |
| Maximum velocity at $F_{max}$ [3] | | $v_{Fmax}$ | m/min | 120 | 90 | 120 |
| Nominal velocity [3] | | $v_N$ | m/min | 190 | 160 | 190 |
| Force constant | | $K_{iFN}$ | N/A | 140 | 161 | 134 |
| Voltage constant [4] | | $K_{EMF}$ | Vs/m | 89 | 142 | 89 |
| Winding resistance at 20°C | | $R_{12}$ | ohms | 4 | 4.3 | 2.6 |
| Winding inductivity | | $L_{12}$ | mH | 23 | 20.6 | 16 |
| Minimum cross-section connection cable [5] | | $A_{PL}$ | mm² | 1.5 | 2.5 | |
| Rated power lossRated power loss | | $P_{vN}$ | W | 1300 | 2512 | |
| Nominal air gap | | δ | mm | $1.0^{+0.55}_{-0.4}$ | | |
| Pole width | | $T_p$ | mm | 37.5 | | |
| Attractive force [6] | | $F_{ATT}$ | N | 7,500 | 11,000 | |
| Primary part mass standard encapsulation | | $m_{PS}$ | kg | 17 | 24.5 | |
| Primary part mass thermal encapsulation | | $m_{PT}$ | kg | 21.2 | 30.1 | |
| Secundary part mass | | $m_S$ | kg/m | 18.8 | | |
| Necessary coolant flow $\Delta\vartheta_N$ [10] | | $Q_{min}$ | l/min | 1.87 | 3.6 | |
| Constant to Determine the Pressure Loss [7] | Standard encapsulation | $k_{dp}$ | | 0.18 | 0.18 | |
| | Thermal encapsulation | | | 0.19 | 0.19 | |
| Pressure loss at $Q_N$ | Standard encapsulation | Δp | bar | 0.54 | 0.87 | |
| | Thermal encapsulation | | | 0.56 | 0.89 | |
| Permissible coolant inlet pressure | | $p_{max}$ | bar | 10 | | |
| Coolant inlet temperature [8] | | $\vartheta_{in}$ | °C | +15 ... +40 | | |
| Temperature rise at $P_{vN}$ [9] | | $\Delta\vartheta_N$ | K | 10 | | |
| Thermal time constant | | $T_{th}$ | min | 6 | | 6.8 |
| Permitted secondary part temperature | | $T_{Smax}$ | °C | 70 | | |
| Admissible ambient temperature during operation | | $T_{amb}$ | °C | 0 ... +40 | | |
| Perm. storage and transport temperature | | $T_L$ | °C | -20 ... +60 | | |
| Degree of protection | | | | IP65 | | |

| Description | Symbol | Unit | MLP140 |
|---|---|---|---|
| Insulation class according to DIN VDE 0530-1 | | | F |

1) The determined values are root-mean-square according to IEC 60034-1, if no others are specified. Reference value 540 $V_{DC}$.

2) The maximum reachable force depends on the drive control device used.

3) The reachable velocities depend on the supply voltage.

4) EMF = electromagnetic force. Effective value referring to 1 m/s.

5) Please note the information on the power wire cross section in "Necessary Power Wire Cross-Section" on page 20.

6) Between primary and secondary part at nominal air gap, primary part currentless.

7) Coolant water. To determine the pressure drop depending on the coolant flow see chapter 9.6 "Motor Cooling System" on page 116.

8) The coolant inlet temperature should be max. 5°C lower than the existing ambient temperature (danger of condensation!).

9) Operation with liquid cooling, coolant water, coolant inlet temperature 30°C.

10) For further notes regarding flow rate, refer to chapter 9.6 "Motor Cooling System" on page 116.

*Fig.4-18: Data sheet frame size MLP140A, MLP140B*

**Motor Characteristic Curves Frame Size 140A, 140B**

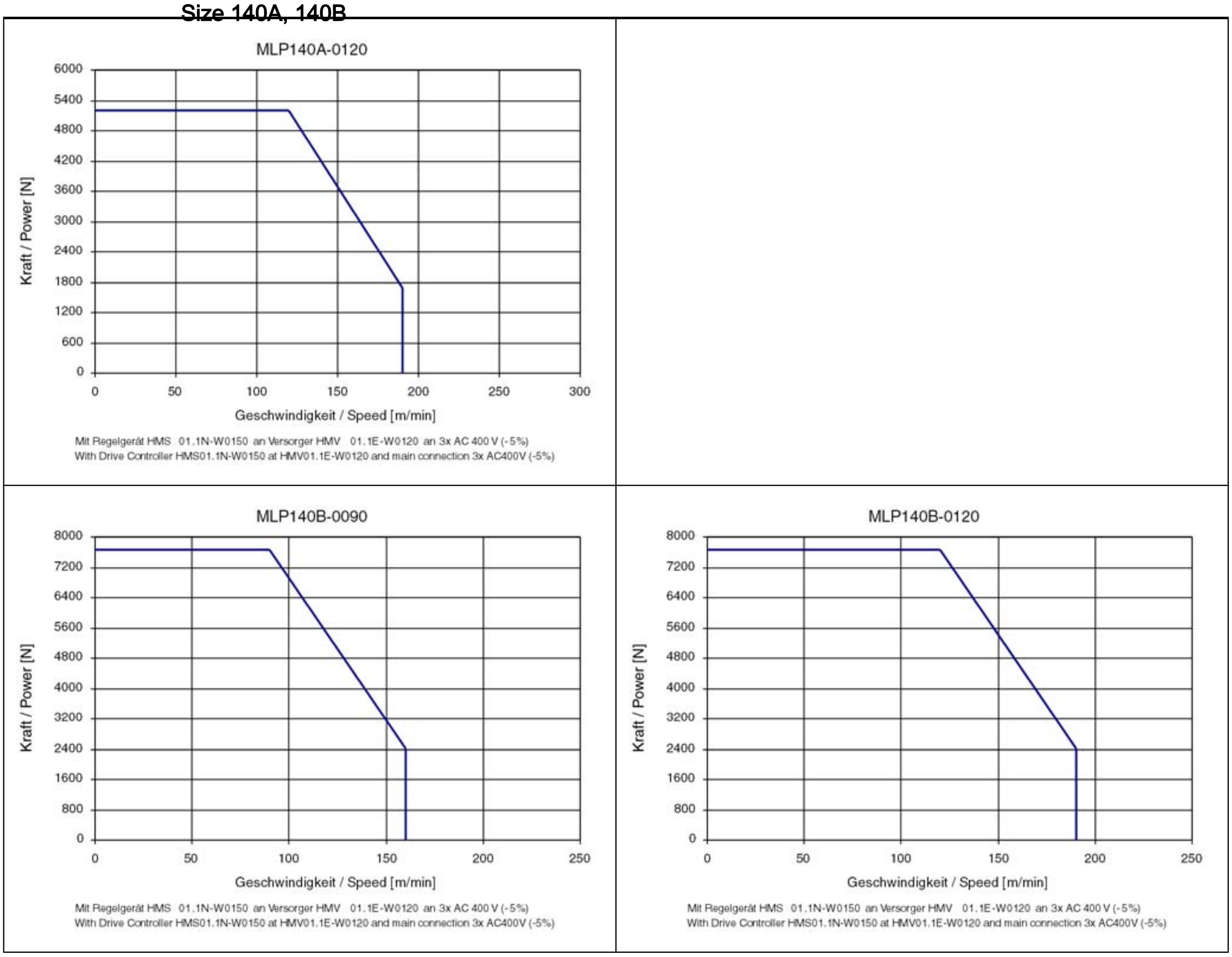



*Fig.4-19: Motor Characteristic Curves Frame Size 140A, 140B*

## 4.5.2 Frame Size MLP140C

| Description | | Symbol | Unit | MLP140C | | | |
|---|---|---|---|---|---|---|---|
| **Motor data** [1] | | | | | | | |
| Winding code | | | | 0050 | 0120 | 0170 | 0350 |
| Appropriate secondary parts | | | | MLS140S-3A-****-NNNN | | | |
| Maximum force [2] | | $F_{max}$ | N | 10,000 | | | |
| Continuous nominal force | | $F_{dN}$ | N | 3,150 | | | |
| Maximum current | | $I_{max}$ | A | 70 | 125 | 140 | 260 |
| Continuous nominal voltage | | $I_{dN}$ | A | 13 | 21 | 29 | 53 |
| Maximum velocity at $F_{max}$ [3] | | $v_{Fmax}$ | m/min | 50 | 120 | 170 | 350 |
| Nominal velocity [3] | | $v_N$ | m/min | 110 | 190 | 250 | 400 |
| Force constant | | $K_{iFN}$ | N/A | 242 | 150 | 109 | 59 |
| Voltage constant [4] | | $K_{EMF}$ | Vs/m | 67 | 96 | 68 | i.p. |
| Winding resistance at 20°C | | $R_{12}$ | ohms | 5,1 | 2.5 | 1.4 | 0.5 |
| Winding inductivity | | $L_{12}$ | mH | 27 | 14 | 7 | 3 |
| Minimum cross-section connection cable [5] | | $A_{PL}$ | mm² | 1.5 | 2.5 | 4 | 10 |
| Rated power loss | | $P_{vN}$ | W | 2,000 | | | |
| Nominal air gap | | δ | mm | $1.0^{+0.55}_{-0.4}$ | | | |
| Pole width | | $T_p$ | mm | 37.5 | | | |
| Attractive force [6] | | $F_{ATT}$ | N | 14,400 | | | |
| Primary part mass standard encapsulation | | $m_{PS}$ | kg | 32 | | | |
| Primary part mass thermal encapsulation | | $m_{PT}$ | kg | 38.9 | | | |
| Secundary part mass | | $m_S$ | kg/m | 18.8 | | | |
| Necessary coolant flow $\Delta\vartheta_N$ [10] | | $Q_{min}$ | l/min | 2.87 | | | |
| Constant to Determine the Pressure Loss [7] | Standard encapsulation | $k_{dp}$ | | 0.18 | | | |
| | Thermal encapsulation | | | 0.19 | | | |
| Pressure loss at $Q_N$ | Standard encapsulation | Δp | bar | 1.15 | | | |
| | Thermal encapsulation | | | 1.18 | | | |
| Permissible coolant inlet pressure | | $p_{max}$ | bar | 10 | | | |
| Coolant inlet temperature [8] | | $\vartheta_{in}$ | °C | +15 ... +40 | | | |
| Temperature rise at $P_{vN}$ [9] | | $\Delta\vartheta_N$ | K | 10 | | | |
| Thermal time constant | | $T_{th}$ | min | 6 | | | |
| Permitted secondary part temperature | | $T_{Smax}$ | °C | 70 | | | |
| Admissible ambient temperature during operation | | $T_{amb}$ | °C | 0 ... +40 | | | |
| Perm. storage and transport temperature | | $T_L$ | °C | -20 ... +60 | | | |
| Degree of protection | | | | IP65 | | | |

| Description | Symbol | Unit | MLP140C |
|---|---|---|---|
| Insulation class according to DIN VDE 0530-1 | | | F |

1) The determined values are root-mean-square according to IEC 60034-1, if no others are specified. Reference value 540 $V_{DC}$.

2) The maximum reachable force depends on the drive control device used.

3) The reachable velocities depend on the supply voltage.

4) EMF = electromagnetic force. Effective value referring to 1 m/s.

5) Please note the information on the power wire cross section in "Necessary Power Wire Cross-Section" on page 20.

6) Between primary and secondary part at nominal air gap, primary part currentless.

7) Coolant water. To determine the pressure drop depending on the coolant flow see chapter 9.6 "Motor Cooling System" on page 116.

8) The coolant inlet temperature should be max. 5°C lower than the existing ambient temperature (danger of condensation!).

9) Operation with liquid cooling, coolant water, coolant inlet temperature 30°C.

10) For further notes regarding flow rate, refer to chapter 9.6 "Motor Cooling System" on page 116.

i. p. = in preparation.

*Fig.4-20: Data sheet frame size MLP140C*

**Motor Characteristic Curves Frame Size 140C**

Technical Data IndraDyn L

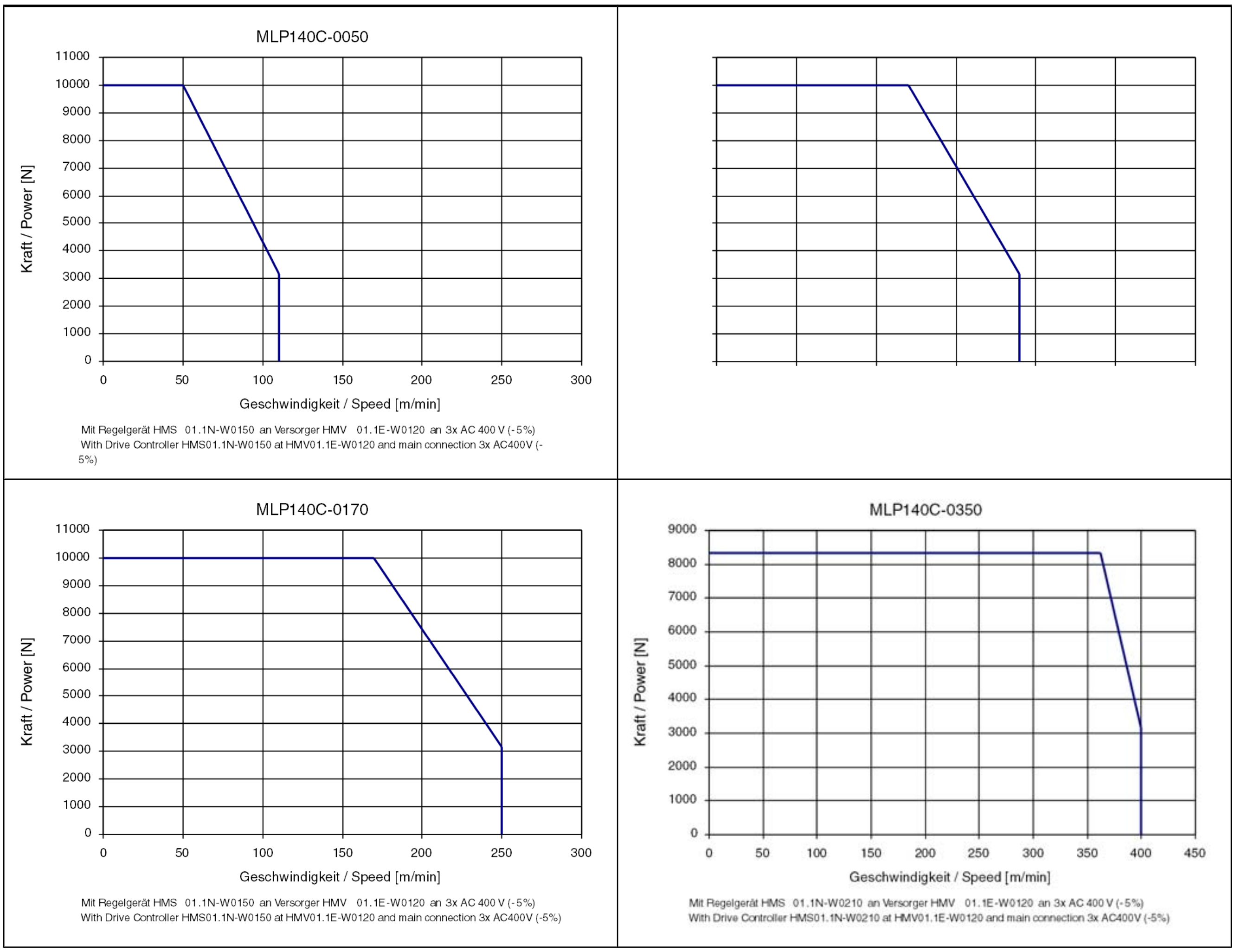



*Fig.4-21: Motor Characteristic Curves Frame Size 140C*

# 4.6 Technical Data - Frame Size MLP200

## 4.6.1 Frame Sizes MLP200A, MLP200B

| Description | Symbol | Unit | MLP200 | | | |
|---|---|---|---|---|---|---|
| **Motor data** 1) | | | | | | |
| Frame length | | | A | | B | |
| Winding code | | | 0090 | 0120 | 0040 | 0120 |
| Appropriate secondary parts | | | MLS200S-3A-****-NNNN | | | |
| Maximum force 2) | $F_{max}$ | N | 7,450 | | 10,900 | |
| Continuous nominal force | $F_{dN}$ | N | 2,415 | | 3,465 | |
| Maximum current | $I_{max}$ | A | 70 | 88 | 70 | 130 |
| Continuous nominal voltage | $I_{dN}$ | A | 13 | 16 | 13 | 22 |
| Maximum velocity at $F_{max}$ 3) | $v_{Fmax}$ | m/min | 90 | 120 | 40 | 120 |
| Nominal velocity 3) | $v_N$ | m/min | 170 | 190 | 100 | 190 |
| Force constant | $K_{iFN}$ | N/A | 186 | 151 | 267 | 158 |
| Voltage constant 4) | $K_{EMF}$ | Vs/m | 100 | 89 | 170 | 89 |
| Winding resistance at 20°C | $R_{12}$ | ohms | 4.5 | 2.3 | 5.8 | 1.7 |
| Winding inductivity | $L_{12}$ | mH | 25 | 14 | 28 | 10 |
| Minimum cross-section connection cable 5) | $A_{PL}$ | mm² | 1.5 | 2.5 | 1.5 | 2.5 |

| Description | | Symbol | Unit | MLP200 | |
|---|---|---|---|---|---|
| Rated power loss | | $P_{vN}$ | W | 1,700 | 2,200 |
| Nominal air gap | | δ | mm | $1.0^{+0.55}_{-0.4}$ | |
| Pole width | | $T_p$ | mm | 37.5 | |
| Attractive force 6) | | $F_{ATT}$ | N | 10,700 | 15,600 |
| Primary part mass standard encapsulation | | $m_{PS}$ | kg | 23 | 33 |
| Primary part mass thermal encapsulation | | $m_{PT}$ | kg | 28.3 | 40 |
| Secundary part mass | | $m_S$ | kg/m | 26.9 | |
| Necessary coolant flow $\Delta\vartheta_N$ 10) | | $Q_{min}$ | l/min | 2.44 | 3.16 |
| Constant to Determine the Pressure Loss 7) | Standard encapsulation | $k_{dp}$ | | 0.18 | 0.18 |
| | Thermal encapsulation | | | 0.19 | 0.19 |
| Pressure loss at $Q_N$ | Standard encapsulation | Δp | bar | 0.88 | 1.38 |
| | Thermal encapsulation | | | 0.9 | 1.41 |
| Permissible coolant inlet pressure | | $p_{max}$ | bar | 10 | |
| Coolant inlet temperature 8) | | $\vartheta_{in}$ | °C | +15 ... +40 | |
| Temperature rise at $P_{vN}$ 9) | | $\Delta\vartheta_N$ | K | 10 | |
| Thermal time constant | | $T_{th}$ | min | 6 | |
| Permitted secondary part temperature | | $T_{Smax}$ | °C | 70 | |
| Admissible ambient temperature during Operation | | $T_{amb}$ | °C | 0 ... +40 | |
| Perm. storage and transport temperature | | $T_L$ | °C | -20 ... +60 | |
| Degree of protection | | | | IP65 | |
| Insulation class according to DIN VDE 0530-1 | | | | F | |

1) The determined values are root-mean-square according to IEC 60034-1, if no others are specified. Reference value 540 $V_{DC}$.

2) The maximum reachable force depends on the drive control device used.

3) The reachable velocities depend on the supply voltage.

4) EMF = electromagnetic force. Effective value referring to 1 m/s.

5) Please note the information on the power wire cross section in "Necessary Power Wire Cross-Section" on page 20.

6) Between primary and secondary part at nominal air gap, primary part currentless.

7) Coolant water. To determine the pressure drop depending on the coolant flow see chapter 9.6 "Motor Cooling System" on page 116.

8) The coolant inlet temperature should be max. 5°C lower than the existing ambient temperature (danger of condensation!).

9) Operation with liquid cooling, coolant water, coolant inlet temperature 30°C.

10) For further notes regarding flow rate, refer to chapter 9.6 "Motor Cooling System" on page 116.

i. p. = in preparation.

*Fig.4-22: Data Sheet Frame Size MLP200A, MLP200B*

**Motor Characteristic Curves Frame Size 200A, 200B**

Technical Data IndraDyn L

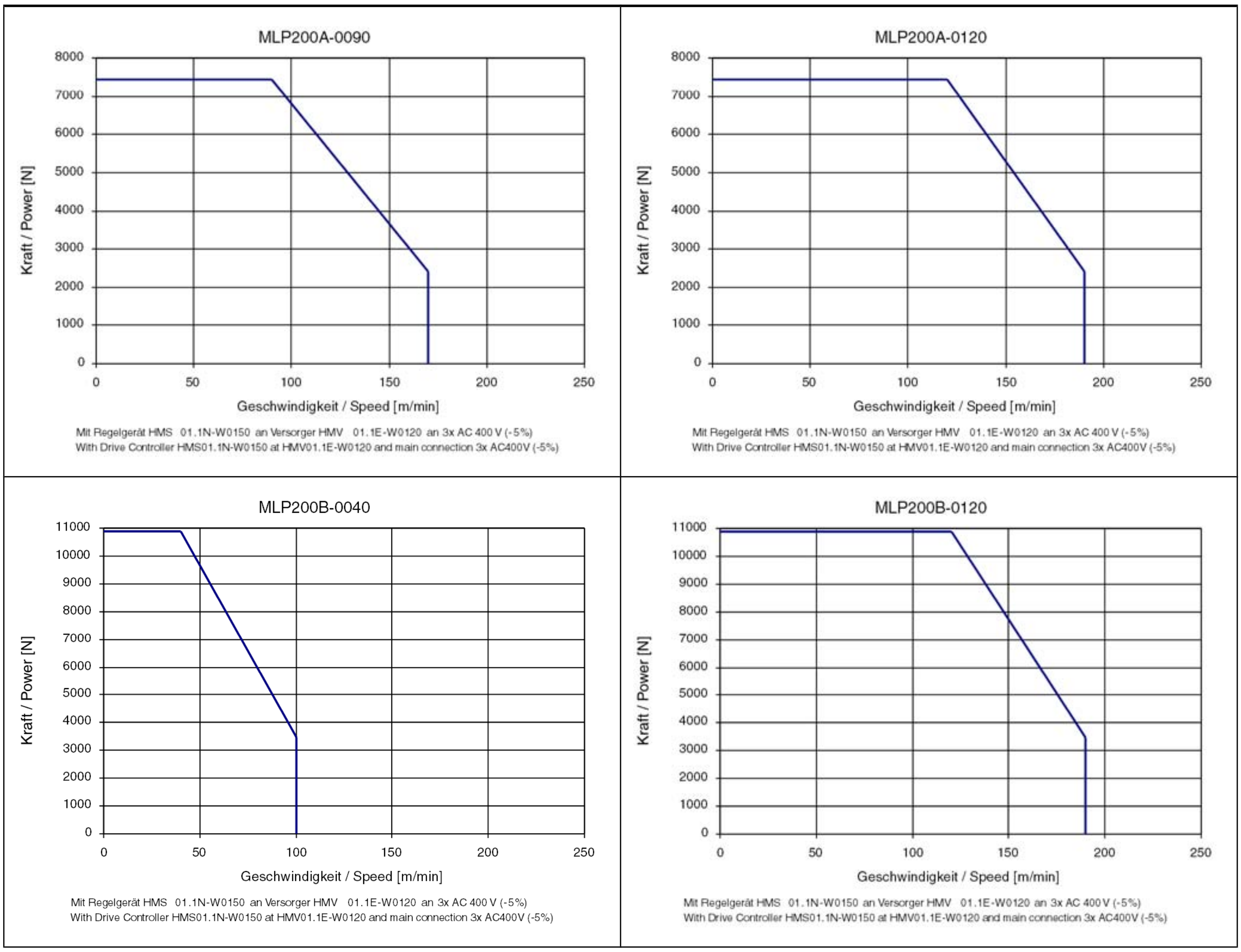



*Fig.4-23: Motor Characteristic Curves Frame Size 200A, 200B*

## 4.6.2 Frame Sizes MLP200C, MLP200D

| Description | Symbol | Unit | MLP200 | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Motor data** 1) | | | | | | | | |
| Frame length | | | C | | | D | | |
| Winding code | | | 0090 | 0120 | 0170 | 0060 | 0100 | 0120 |
| Appropriate secondary parts | | | MLS200S-3A-****-NNNN | | | | | |
| Maximum force 2) | $F_{max}$ | N | 14,250 | | | 17,750 | | |
| Continuous nominal force | $F_{dN}$ | N | 4,460 | | | 5,560 | | |
| Maximum current | $I_{max}$ | A | 120 | 175 | 210 | 140 | 210 | 225 |
| Continuous nominal voltage | $I_{dN}$ | A | 23.3 | 30 | 46 | 28 | 46 | 53 |
| Maximum velocity at $F_{max}$ 3) | $v_{Fmax}$ | m/min | 90 | 120 | 170 | 60 | 100 | 120 |
| Nominal velocity 3) | $v_N$ | m/min | 170 | 190 | 220 | 140 | 180 | 190 |
| Force constant | $K_{iFN}$ | N/A | 191 | 149 | 97 | 220 | 121 | 105 |
| Voltage constant 4) | $K_{EMF}$ | Vs/m | 114 | 89 | 77 | 216 | 94 | 89 |
| Winding resistance at 20°C | $R_{12}$ | ohms | 2.7 | 1.7 | 1.1 | 2.8 | 1.6 | 1.3 |
| Winding inductivity | $L_{12}$ | mH | 13 | 8 | 5 | 15 | 8.1 | 6 |
| Minimum cross-section connection cable 5) | $A_{PL}$ | mm² | 4 | 6 | 10 | 4 | 10 | 10 |
| Rated power loss | $P_{vN}$ | W | 2,700 | | | 4,969 | | |

| Description | | Symbol | Unit | MLP200 | |
|---|---|---|---|---|---|
| Nominal air gap | | δ | mm | $1.0^{+0.55}_{-0.4}$ | |
| Pole width | | $T_p$ | mm | 37.5 | |
| Attractive force [6)] | | $F_{ATT}$ | N | 20,500 | 25,400 |
| Primary part mass standard encapsulation | | $m_{PS}$ | kg | 42 | 51 |
| Primary part mass thermal encapsulation | | $m_{PT}$ | kg | 50.7 | 61.3 |
| Secundary part mass | | $m_S$ | kg/m | 26.9 | |
| Necessary coolant flow $\Delta\vartheta_N$ [10)] | | $Q_{min}$ | l/min | 3.88 | 8 |
| Constant to Determine the Pressure Loss [7)] | Standard encapsulation | $k_{dp}$ | | 0.19 | 0.19 |
| | Thermal encapsulation | | | 0.19 | 0.19 |
| Pressure loss at $Q_N$ | Standard encapsulation | Δp | bar | 1.99 | 2.4 |
| | Thermal encapsulation | | | 2.04 | 2.45 |
| Permissible coolant inlet pressure | | $p_{max}$ | bar | 10 | |
| Coolant inlet temperature [8)] | | $\vartheta_{in}$ | °C | +15 ... +40 | |
| Temperature rise at $P_{vN}$ [9)] | | $\Delta\vartheta_N$ | K | 10 | |
| Thermal time constant | | $T_{th}$ | min | 6.6 | 6 |
| Permitted secondary part temperature | | $T_{Smax}$ | °C | 70 | |
| Admissible ambient temperature during Operation | | $T_{amb}$ | °C | 0 ... +40 | |
| Perm. storage and transport temperature | | $T_L$ | °C | -20 ... +60 | |
| Degree of protection | | | | IP65 | |
| Insulation class according to DIN VDE 0530-1 | | | | F | |

1) The determined values are root-mean-square according to IEC 60034-1, if no others are specified. Reference value 540 $V_{DC}$.

2) The maximum reachable force depends on the drive control device used.

3) The reachable velocities depend on the supply voltage.

4) EMF = electromagnetic force. Effective value referring to 1 m/s.

5) Please note the information on the power wire cross section in "Necessary Power Wire Cross-Section" on page 20.

6) Between primary and secondary part at nominal air gap, primary part currentless.

7) Coolant water. To determine the pressure drop depending on the coolant flow see chapter 9.6 "Motor Cooling System" on page 116.

8) The coolant inlet temperature should be max. 5°C lower than the existing ambient temperature (danger of condensation!).

9) Operation with liquid cooling, coolant water, coolant inlet temperature 30°C.

10) For further notes regarding flow rate, refer to chapter 9.6 "Motor Cooling System" on page 116.

*Fig.4-24: Data Sheet Frame Size MLP200C, MLP200D*

**Motor Characteristic Curves Frame Size 200C, 200D**

Technical Data IndraDyn L

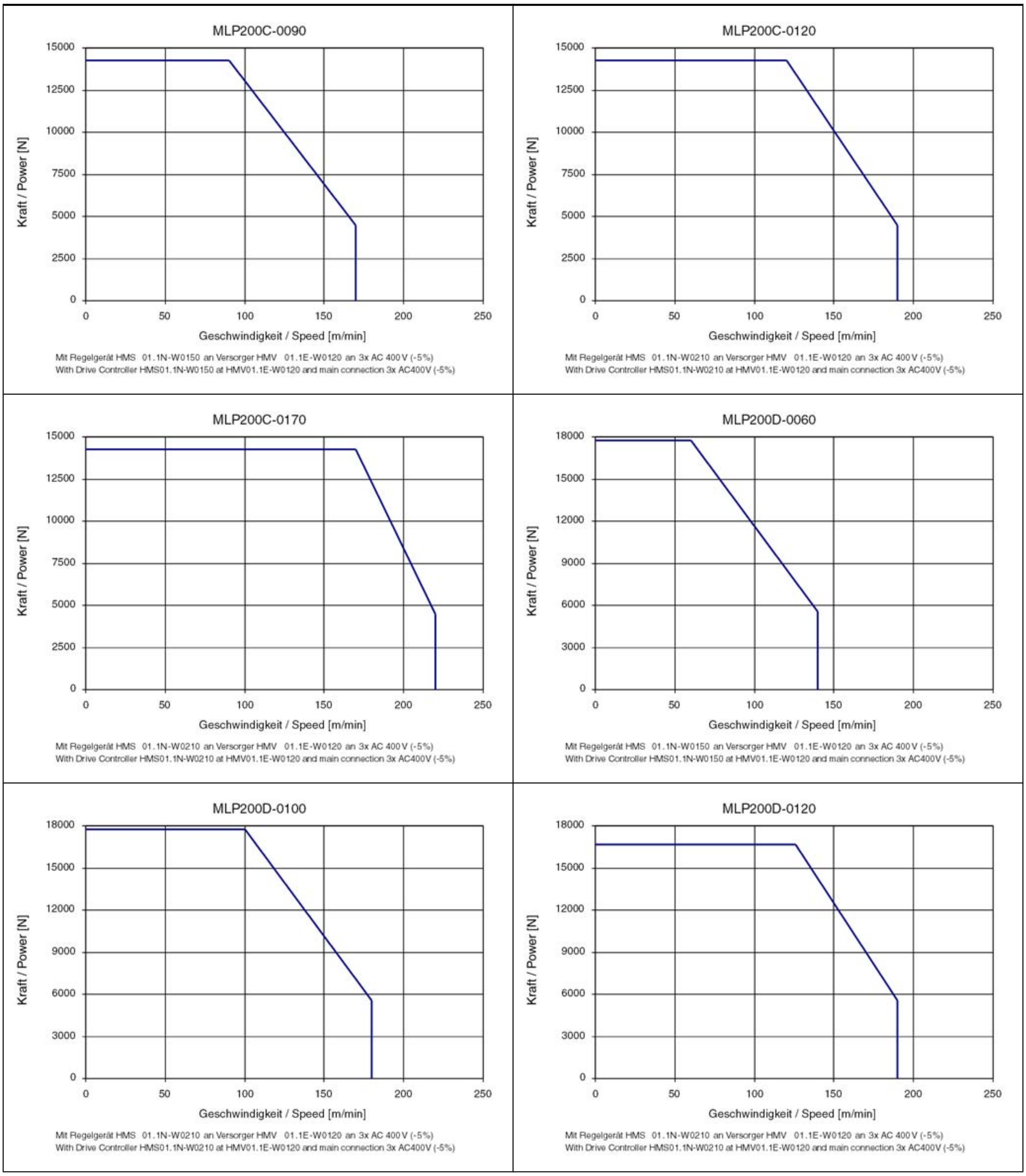



*Fig.4-25: Motor Characteristic Curves Frame Size 200C, 200D*

## 4.7 Technical Data - Frame Size MLP300

| Description | Symbol | Unit | MLP300 | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Motor data** [1] | | | | | | | | |
| Frame length | | | A | | B | | C | |
| Winding code | | | 0090 | 0120 | 0070 | 0120 | 0060 | 0090 |
| Appropriate secondary parts | | | MLS300S-3A-****-HNNN | | | | | |
| Maximum force [2] | $F_{max}$ | N | 11,000 | | 16,300 | | 21,500 | |
| Continuous nominal force | $F_{dN}$ | N | 3,350 | | 5,150 | | 6,720 | |
| Maximum current | $I_{max}$ | A | 110 | 138 | 140 | 205 | 140 | 212 |
| Continuous nominal voltage | $I_{dN}$ | A | 19 | 23 | 28 | 35 | 29 | 37 |
| Maximum velocity at $F_{max}$ [3] | $v_{Fmax}$ | m/min | 90 | 120 | 70 | 120 | 60 | 90 |
| Nominal velocity [3] | $v_N$ | m/min | 160 | 190 | 140 | 190 | 110 | 150 |
| Force constant | $K_{iFN}$ | N/A | 176 | 146 | 184 | 147 | 232 | 182 |
| Voltage constant [4] | $K_{EMF}$ | Vs/m | 106 | 89 | 121 | 89 | 155 | 113 |
| Winding resistance at 20°C | $R_{12}$ | ohms | 3.1 | 2 | 2.7 | 1.3 | 1.4 | 1.6 |
| Winding inductivity | $L_{12}$ | mH | 15 | 9.3 | 14 | 6.7 | 12.2 | 8 |
| Minimum cross-section connection cable [5] | $A_{PL}$ | mm² | 2.5 | 4 | 4 | 6 | 4 | 6 |
| Rated power loss | $P_{vN}$ | W | 2,200 | | 2,900 | | 3,200 | |
| Nominal air gap | δ | mm | $1.2^{+0.56}_{-0.4}$ | | | | | |
| Pole width | $T_p$ | mm | 37.5 | | | | | |
| Attractive force [6] | $F_{ATT}$ | N | 16,000 | | 23,400 | | 30,700 | |
| Primary part mass standard encapsulation | $m_{PS}$ | kg | 33 | | 48 | | 62 | |
| Primary part mass thermal encapsulation | $m_{PT}$ | kg | 40.8 | | 58.3 | | 74.9 | |
| Secundary part mass | $m_S$ | kg/m | 45.4 | | | | | |
| Necessary coolant flow $\Delta\vartheta_N$ [10] | $Q_{min}$ | l/min | 3.16 | | 4.17 | | 4.6 | |
| Constant to Determine the Pressure Loss [7] – Standard encapsulation | $k_{dp}$ | | 0.19 | | 0.19 | | 0.19 | |
| Constant to Determine the Pressure Loss [7] – Thermal encapsulation | $k_{dp}$ | | 0.19 | | 0.19 | | 0.19 | |
| Pressure loss at $Q_N$ – Standard encapsulation | Δp | bar | 1.41 | | 2.29 | | 2.72 | |
| Pressure loss at $Q_N$ – Thermal encapsulation | Δp | bar | 1.44 | | 2.34 | | 2.78 | |
| Permissible coolant inlet pressure | $p_{max}$ | bar | 10 | | | | | |
| Coolant inlet temperature [8] | $\vartheta_{in}$ | °C | +15 ... +40 | | | | | |
| Temperature rise at $P_{vN}$ [9] | $\Delta\vartheta_N$ | K | 10 | | | | | |
| Thermal time constant | $T_{th}$ | min | 6 | | 6 | | 6 | |
| Permitted secondary part Temperature | $T_{Smax}$ | °C | 70 | | | | | |
| Admissible ambient temperature during operation | $T_{amb}$ | °C | 0 ... +40 | | | | | |
| Perm. storage and transport temperature | $T_L$ | °C | -20 ... +60 | | | | | |
| Degree of protection | | | IP65 | | | | | |

Technical Data IndraDyn L

| Description | Symbol | Unit | MLP300 |
|---|---|---|---|
| Insulation class according to DIN VDE 0530-1 | | | F |
| 1) The determined values are root-mean-square according to IEC 60034-1, if no others are specified. Reference value 540 $V_{DC}$.<br>2) The maximum reachable force depends on the drive control device used.<br>3) The reachable velocities depend on the supply voltage.<br>4) EMF = electromagnetic force. Effective value referring to 1 m/s.<br>5) Please note the information on the power wire cross section in "Necessary Power Wire Cross-Section" on page 20.<br>6) Between primary and secondary part at nominal air gap, primary part currentless.<br>7) Coolant water. To determine the pressure drop depending on the coolant flow see chapter 9.6 "Motor Cooling System" on page 116.<br>8) The coolant inlet temperature should be max. 5°C lower than the existing ambient temperature (danger of condensation!).<br>9) Operation with liquid cooling, coolant water, coolant inlet temperature 30°C.<br>10) For further notes regarding flow rate, refer to chapter 9.6 "Motor Cooling System" on page 116.<br>i. p. = in preparation. | | | |

*Fig.4-26: Data sheet frame size MLP300*

**Motor Characteristic Curves Frame Size 300**

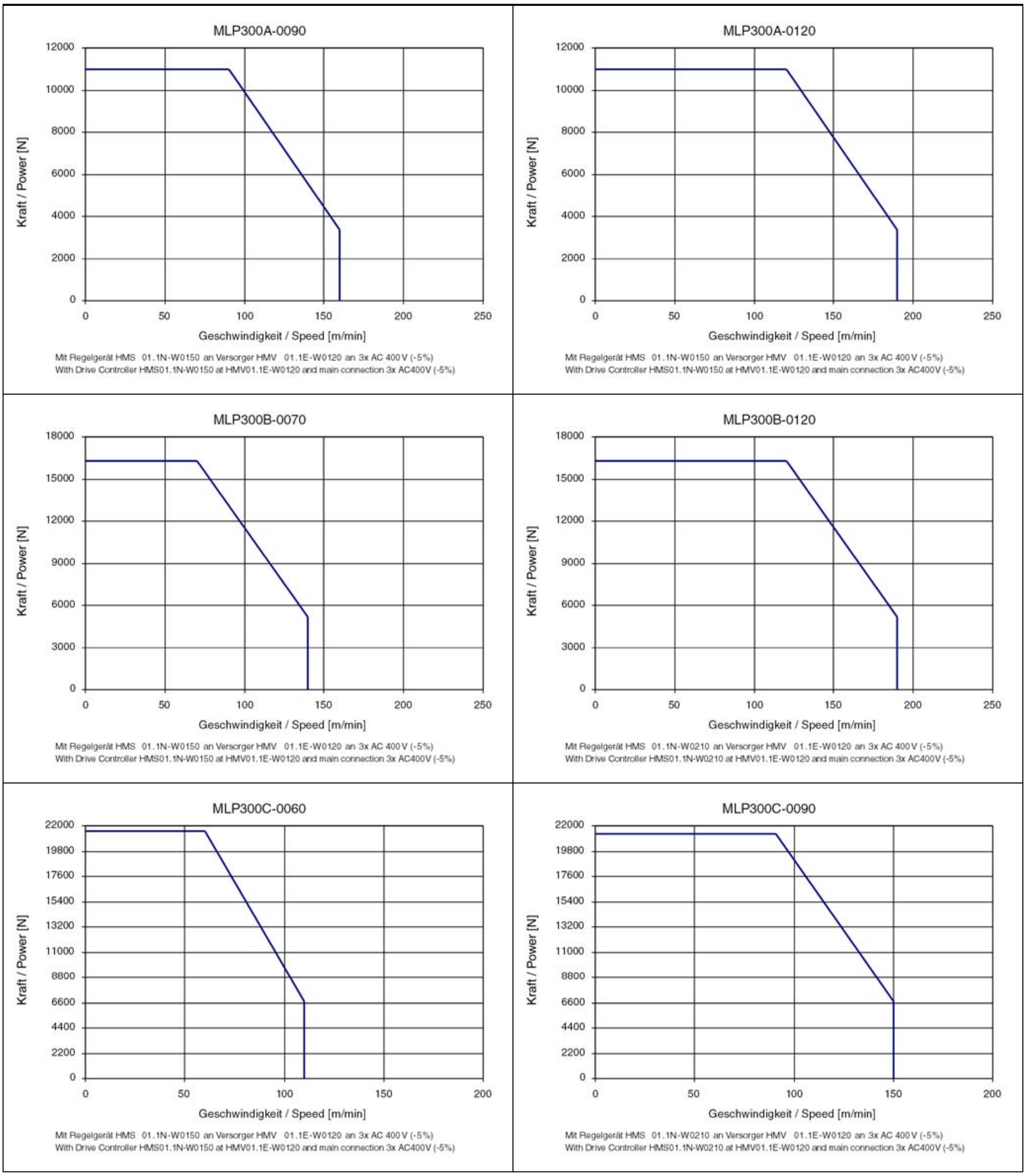



*Fig.4-27: Motor Characteristic Curves Frame Size 300*

# 5 Dimensions, Installation Dimensions and -Tolerances

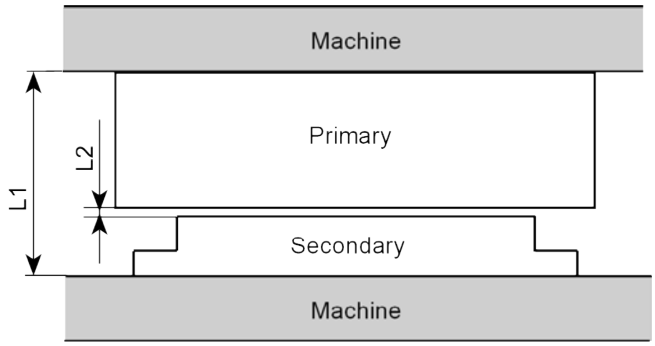
## 5.1 Installation Tolerances

In order to ensure a constant force along the entire travel length, a defined air gap height must be guaranteed. For this purpose, the individual parts of the motor (primary and secondary part) are tolerated accordingly. The distance of the mounting surface, the parallelism and the symmetry of the primary and secondary part of the linear motor in the machine must be within a certain tolerance above the entire travel length. Any deformations that result from weight, attractive forces and process forces must be taken into account. A deviation of the specified nominal air gap may lead

- to a reduction or modification of the specified performance data
- to a contact between the primary part and the secondary part and thus to damaged and destroyed motor components.

For the installation of the motors into the machine structure, Bosch Rexroth specifies a defined installation height with tolerances (see installation size L1 in fig. 5-1 "Mounting Sizes and Tolerances" on page 49). Thus, the specified size and tolerances of the air gap are maintained automatically – even if individual motor components are replaced.

**Installation Height**




| Frame size Primary part | Design Primary part | Design Secondary part | Installation height L1 | Measurable air gap L2 |
|---|---|---|---|---|
| 40...200 | Standard encapsulation | MLSxxxS-* | $61.4^{+0.1}$ | $1.0^{+0.66}_{-0.4}$ |
| 300 | Standard encapsulation | | $72.5^{+0.1}$ | $1.2^{+0.56}_{-0.4}$ |
| | | | | |
| 040...200 | Thermal encapsulation | | $73.9^{+0.1}$ | $1.0^{+0.66}_{-0.4}$ |
| 300 | Thermal encapsulation | | $87.0^{+0.1}$ | $1.2^{+0.56}_{-0.4}$ |

*Fig.5-1: Mounting Sizes and Tolerances*

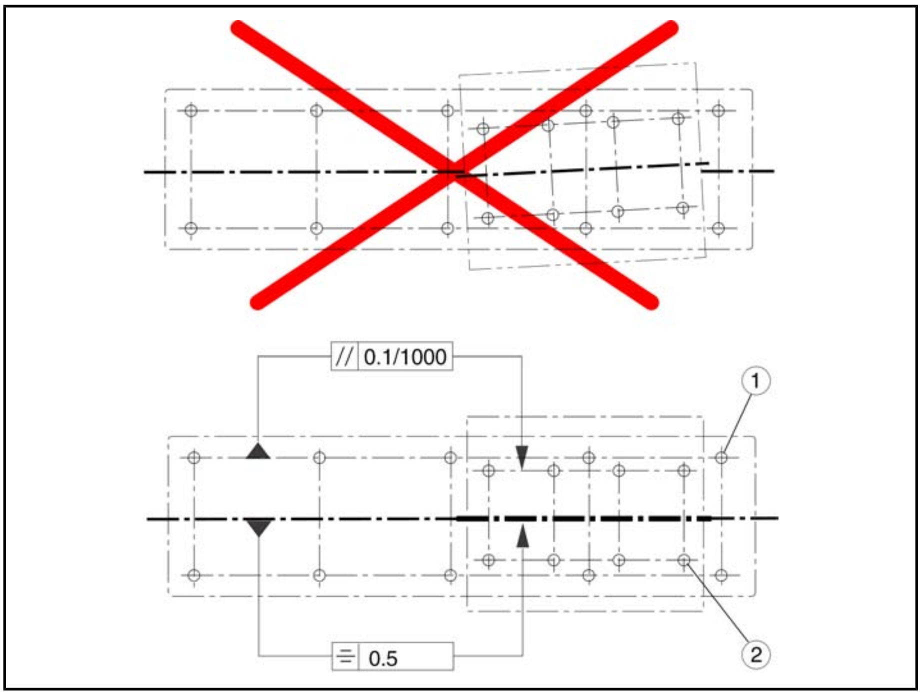
☞ The specified installation height with the corresponding tolerances has to be observed absolutely.

**Parallelism and Symmetry of Machine Parts**

Before primary and secondary part can be mounted, align the parts of the machine. Especially the machine slide is to be brought into a defined position to the machine bed. When aligning, the installation dimensions and tolerances regarding parallelism and symmetry according to fig. 5-2 "Parallelism and symmetry between the fastening holes for the primary part and the fastening threads for the secondary part" on page 50 must be kept.

To keep the tolerances, it is necessary that the fastening holes for the primary part and the threaded holes for the secondary part in the machine are strictly done according to the dimensions of the particular dimension sheets.

If this is done correctly, the center lines of the fastening of threaded holes can serve as referance for aligning the parts.




① Drilling pattern (fastening threads) for the secondary part
② Drilling pattern (fastening holes) for primary part

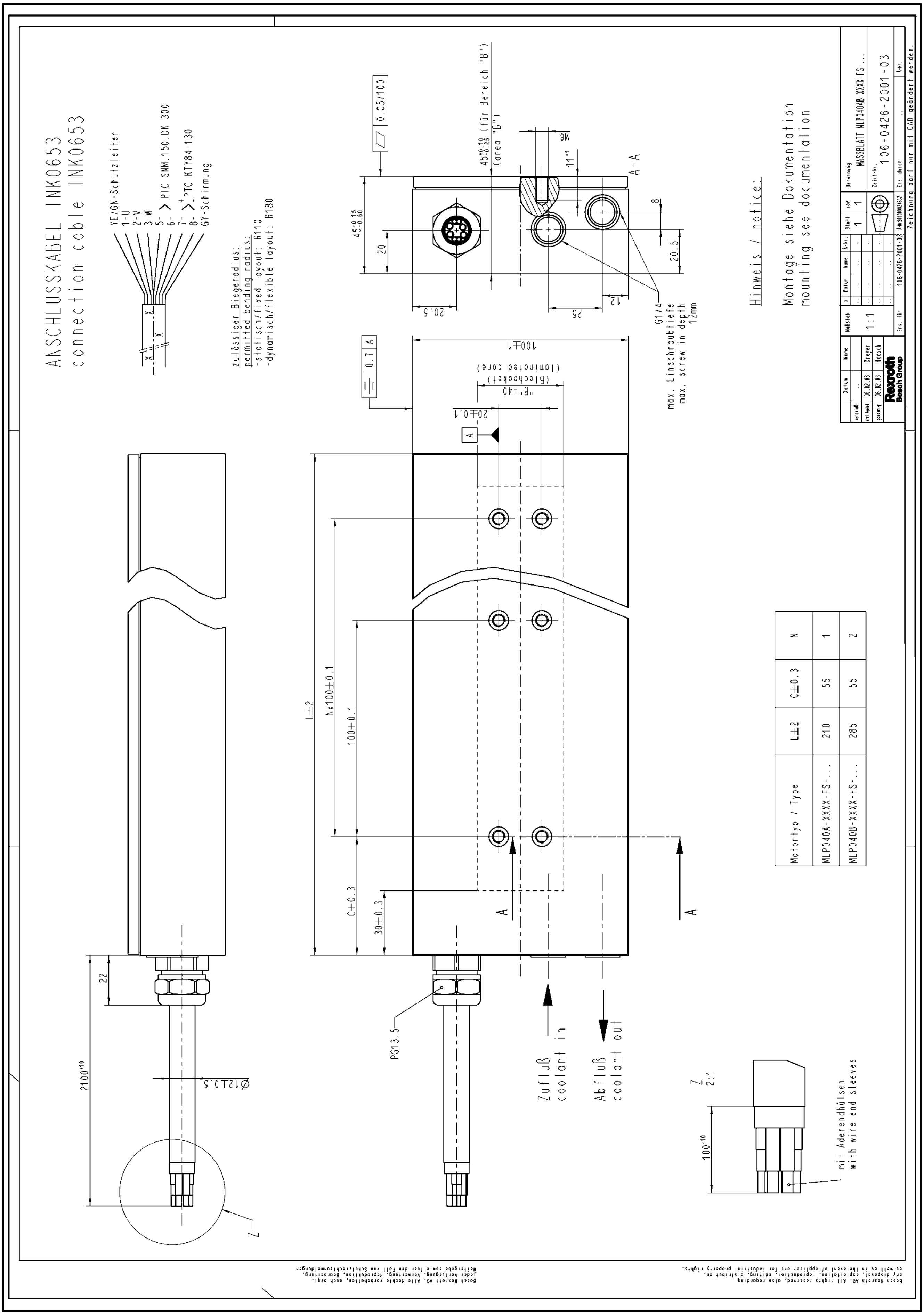
*Fig.5-2: Parallelism and symmetry between the fastening holes for the primary part and the fastening threads for the secondary part*

When moving primary and secondary parts, the stated tolerances regarding parallelism and symmetry must be kept during the total moving process.

You will find further notes regarding assembly of primary and secondary parts in the chapter 13 "Assembly".

# 5.2 Dimension Sheets Frame Size 040

## 5.2.1 Primary Part MLP040 with Standard Encapsulation




| Motortyp / Type | L±2 | C±0.3 | N |
|---|---|---|---|
| MLP040A-XXXX-FS-... | 210 | 55 | 1 |
| MLP040B-XXXX-FS-... | 285 | 55 | 2 |

Dimensions, Installation Dimensions and -Tolerances

## 5.2.2 Primary Part MLP040 with Thermo Encapsulation

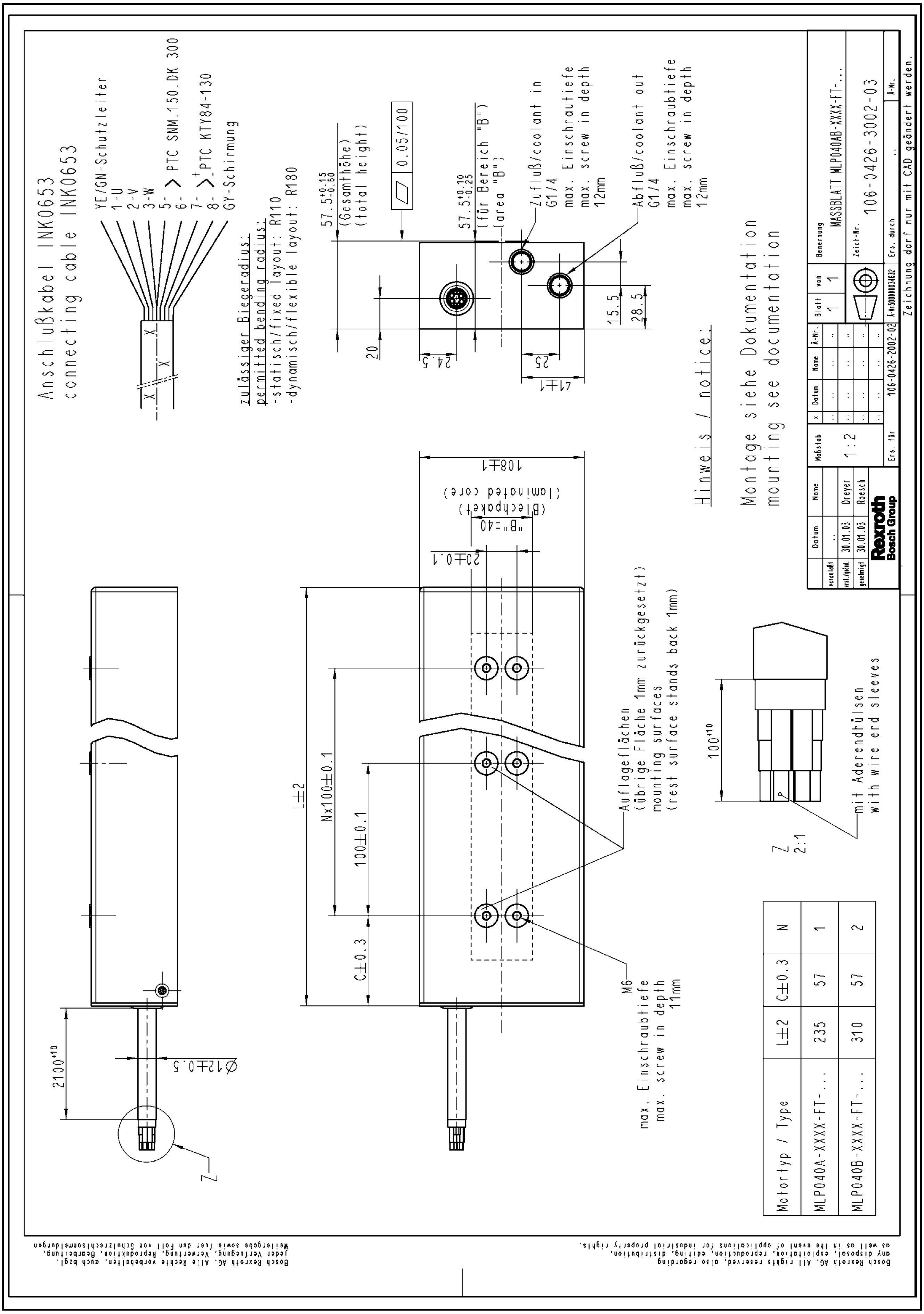


Fig.5-4: Primary Part MLP040 with Thermo Encapsulation

### 5.2.3 Secondary Part MLS040

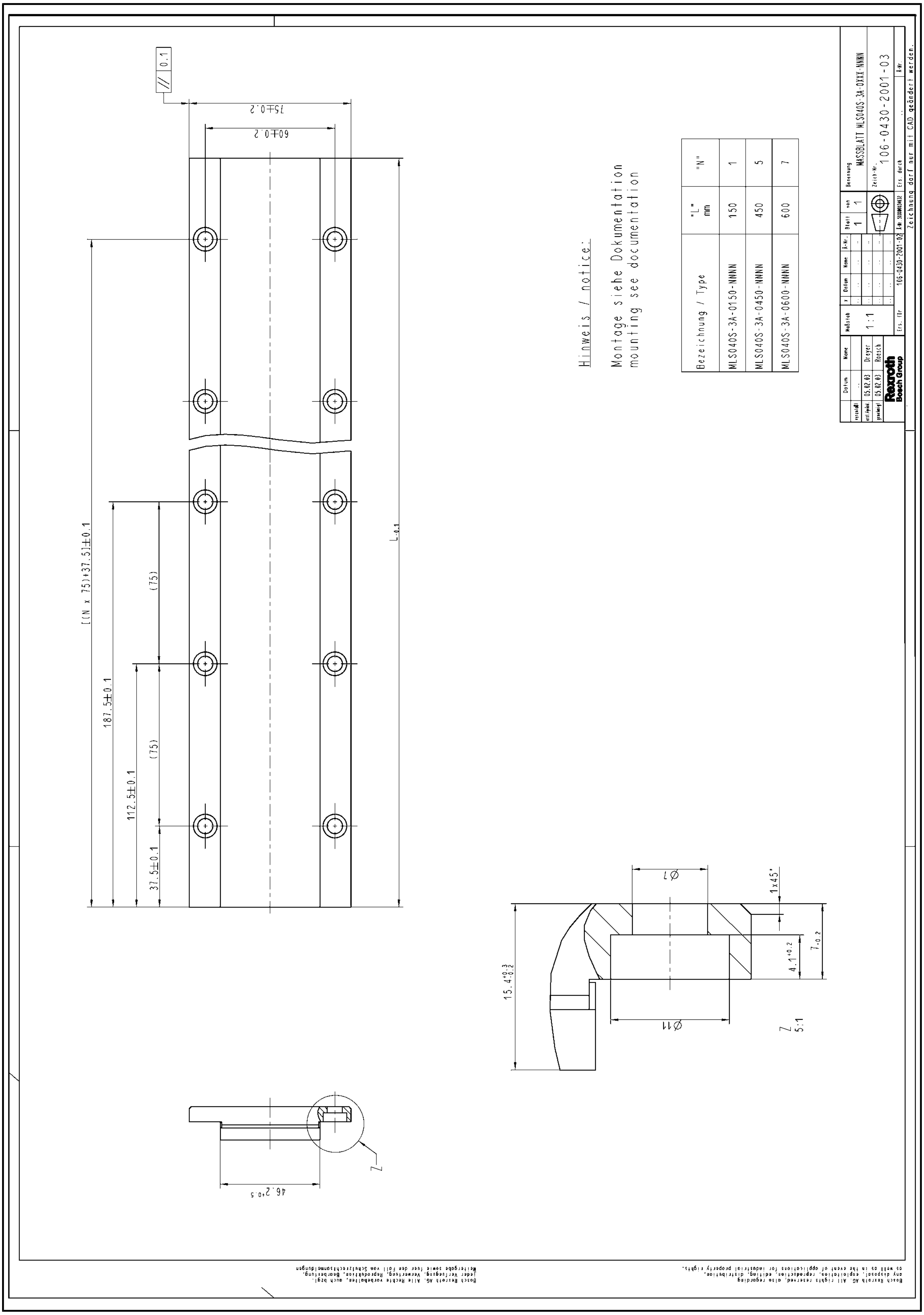
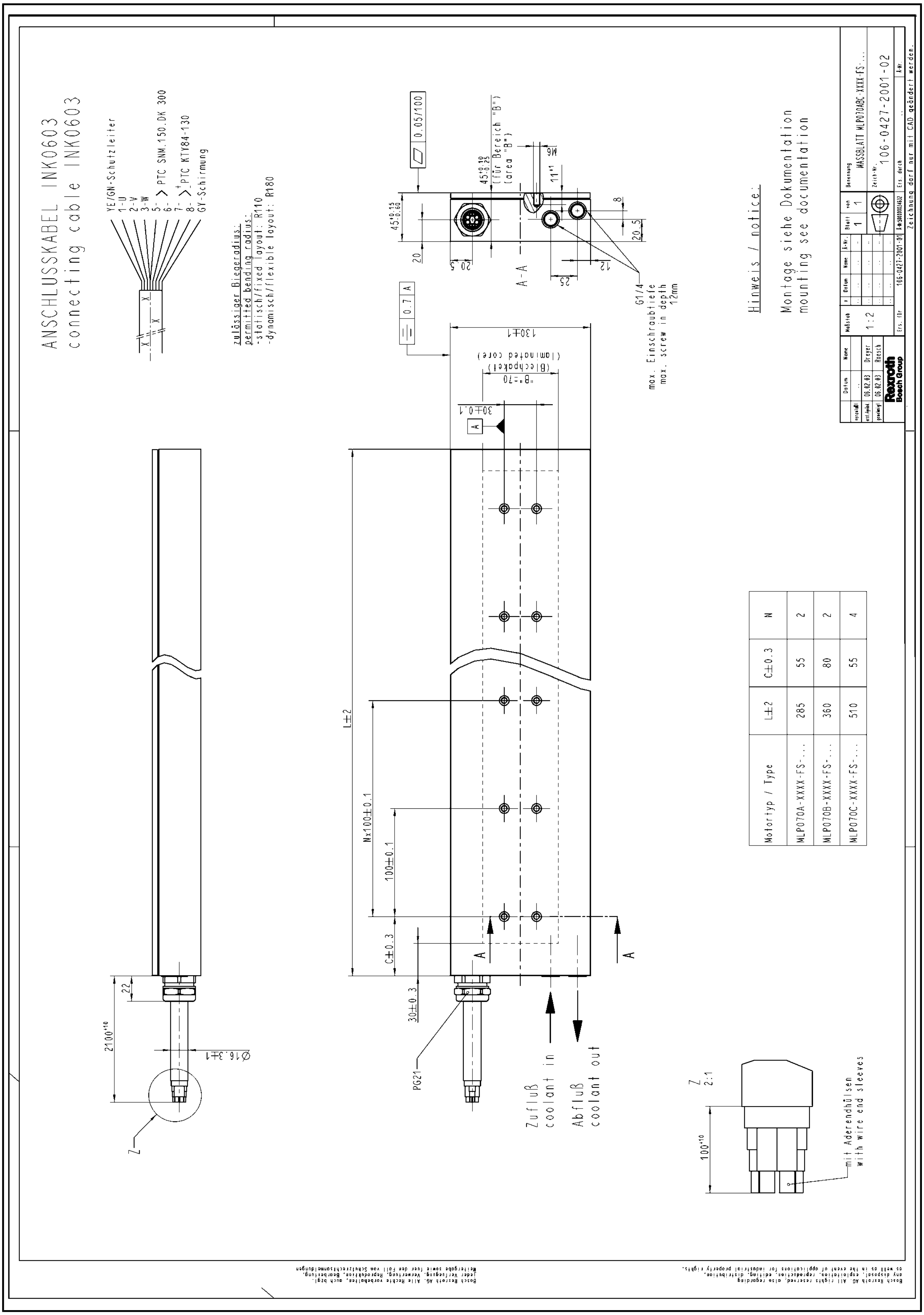


Fig.5-5: Secondary Part MLS040

# 5.3 Dimension Sheets Frame Size 070

## 5.3.1 Primary Part MLP070 with Standard Encapsulation



## 5.3.2 Primary Part MLP070 with Thermo Encapsulation

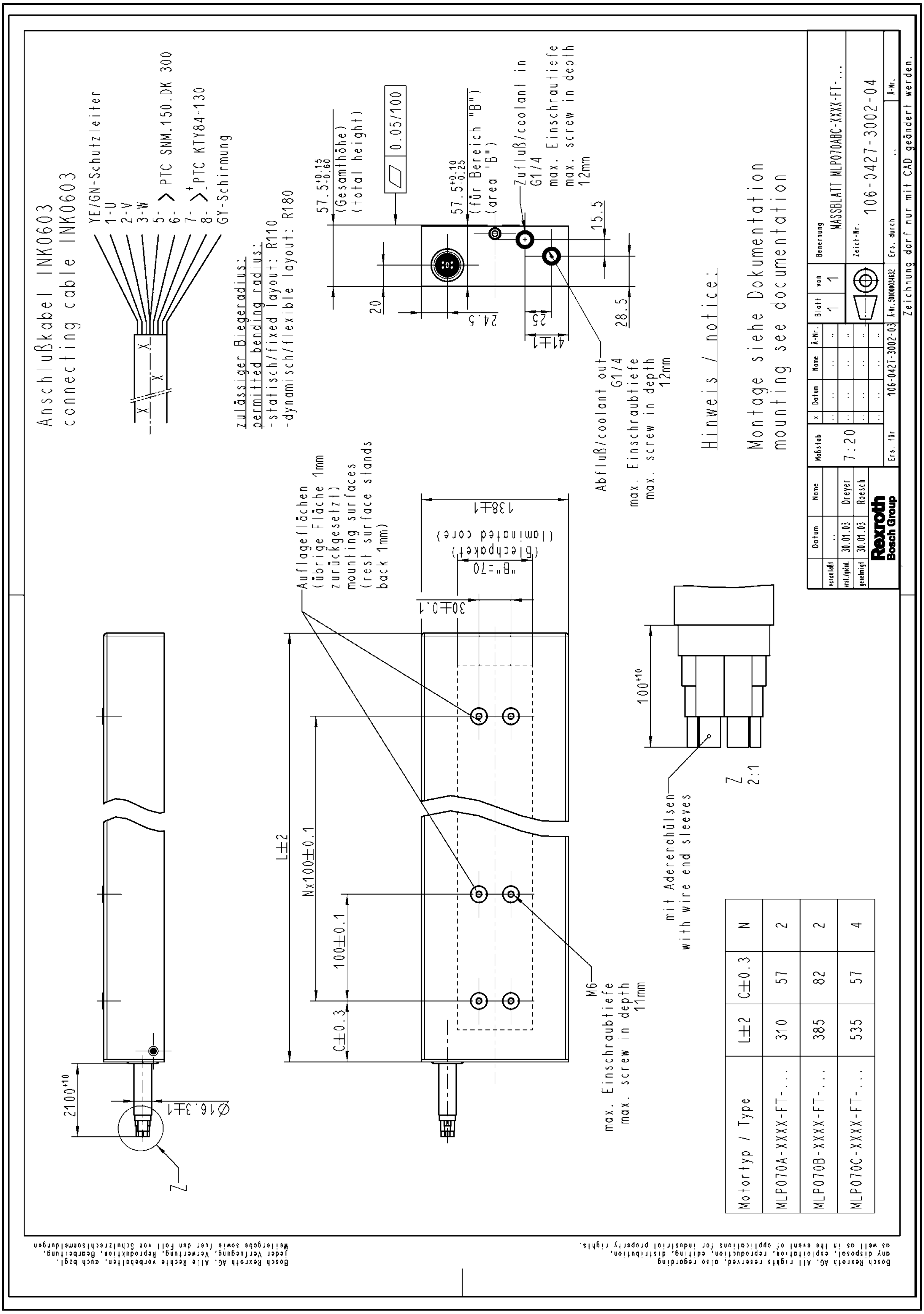



*Fig.5-7: Primary Part MLP070 with Thermo Encapsulation*

Dimensions, Installation Dimensions and -Tolerances

## 5.3.3 Secondary Part MLS070

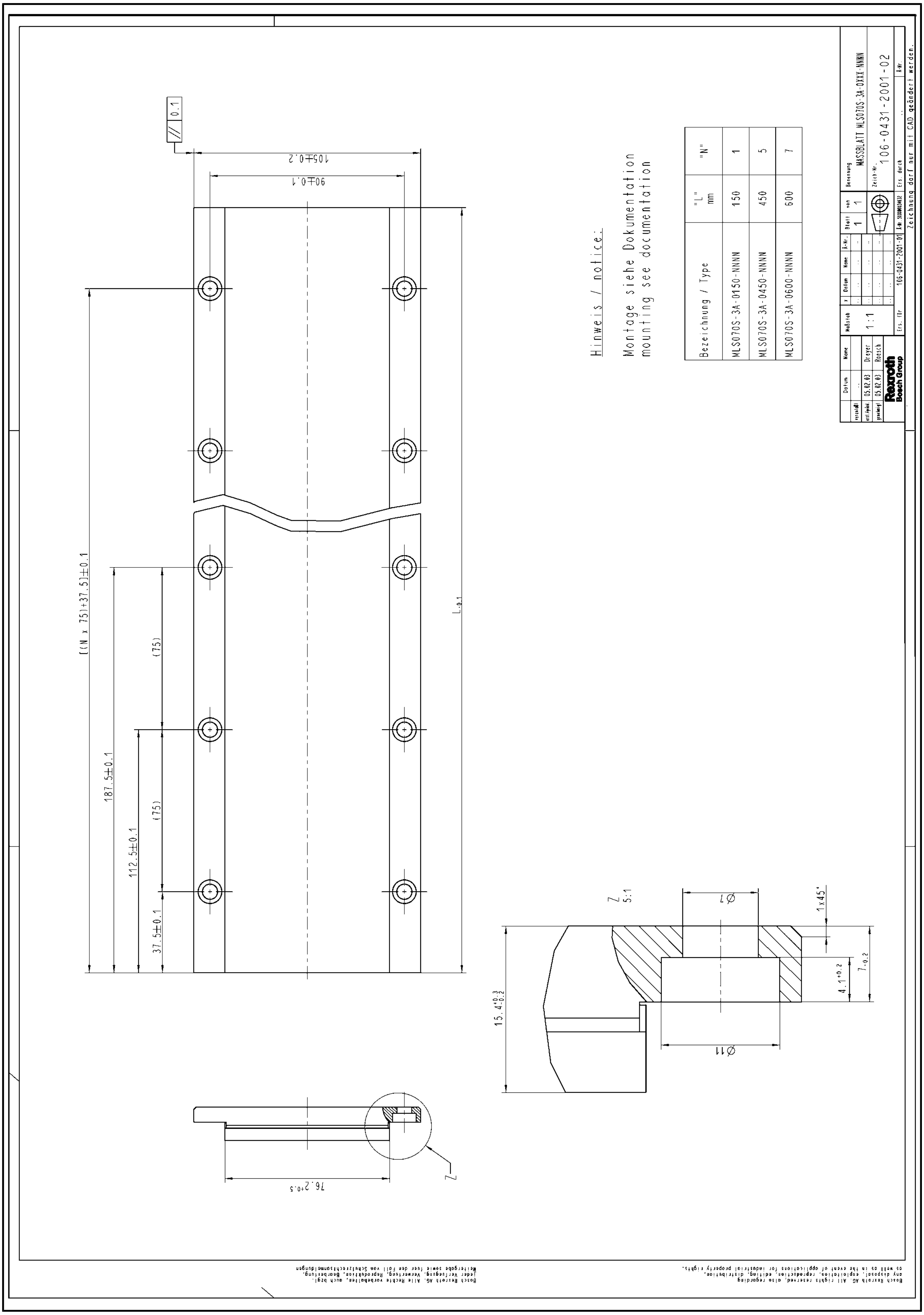
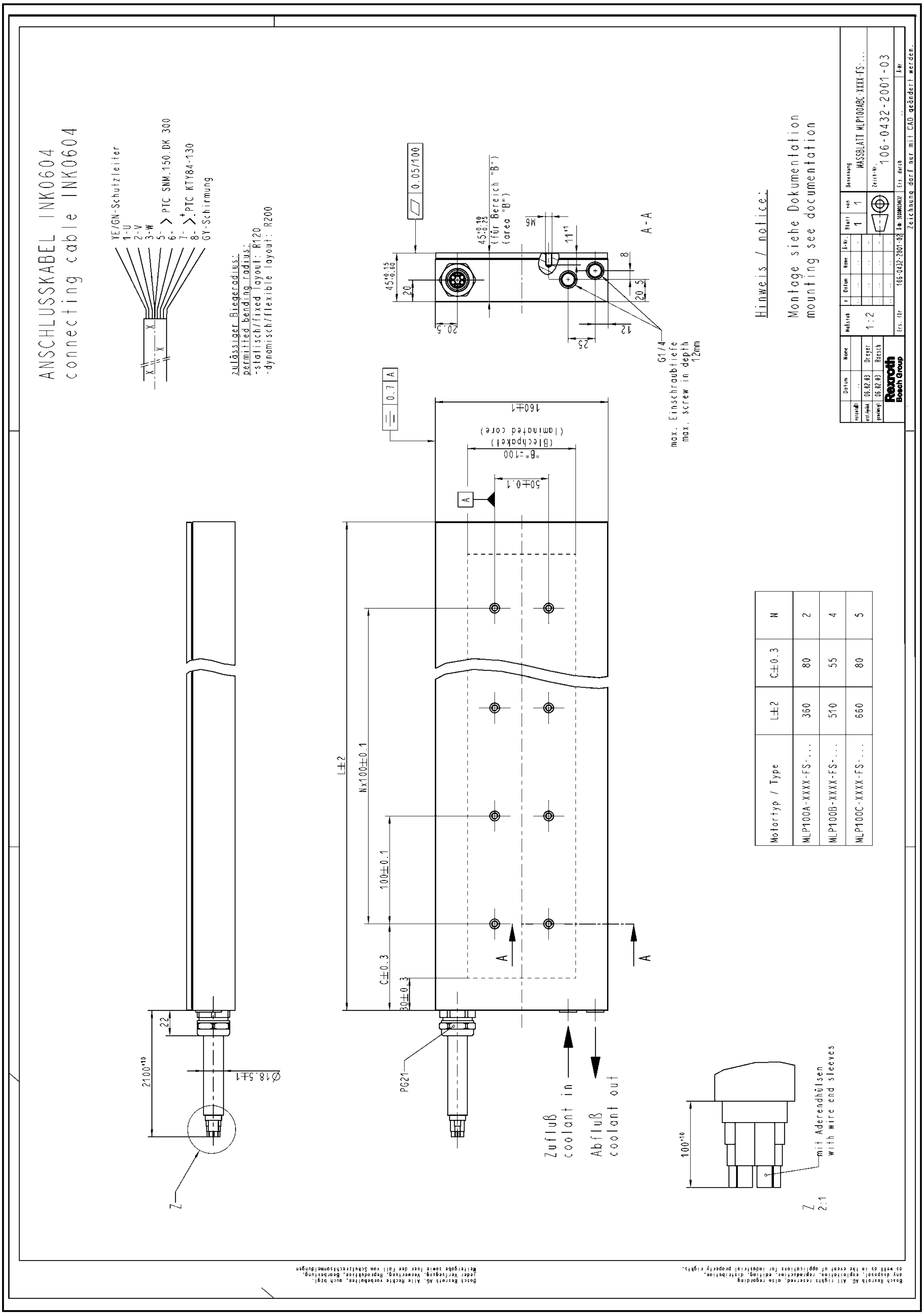


*Fig.5-8: Secondary Part MLS070*

## 5.4 Dimension Sheets Frame Size 100

### 5.4.1 Primary Part MLP100 with Standard Encapsulation



## 5.4.2 Primary Part MLP100 with Thermo Encapsulation

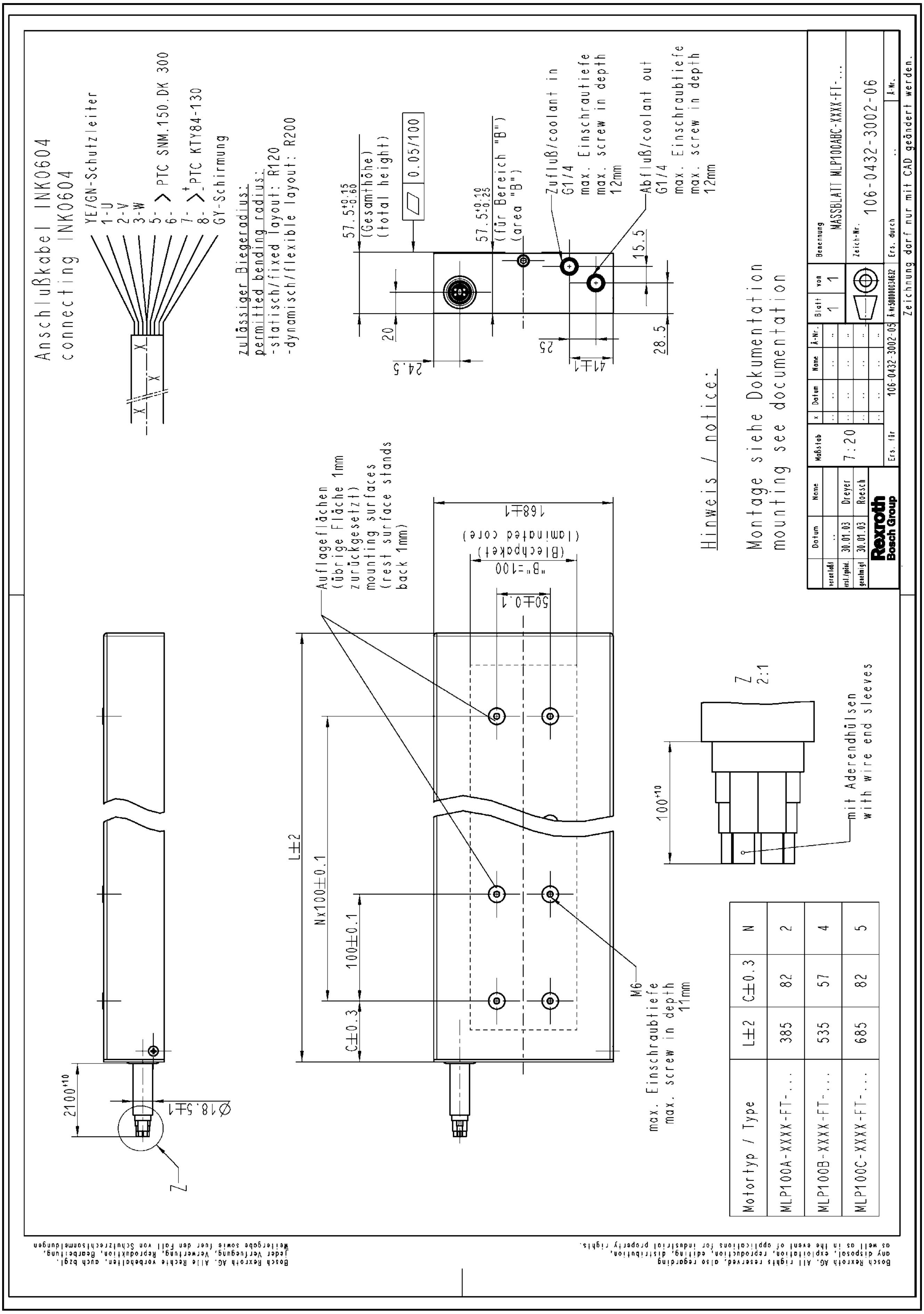


*Fig.5-10: Primary Part MLP100 with Thermo Encapsulation*

### 5.4.3 Secondary Part MLS100

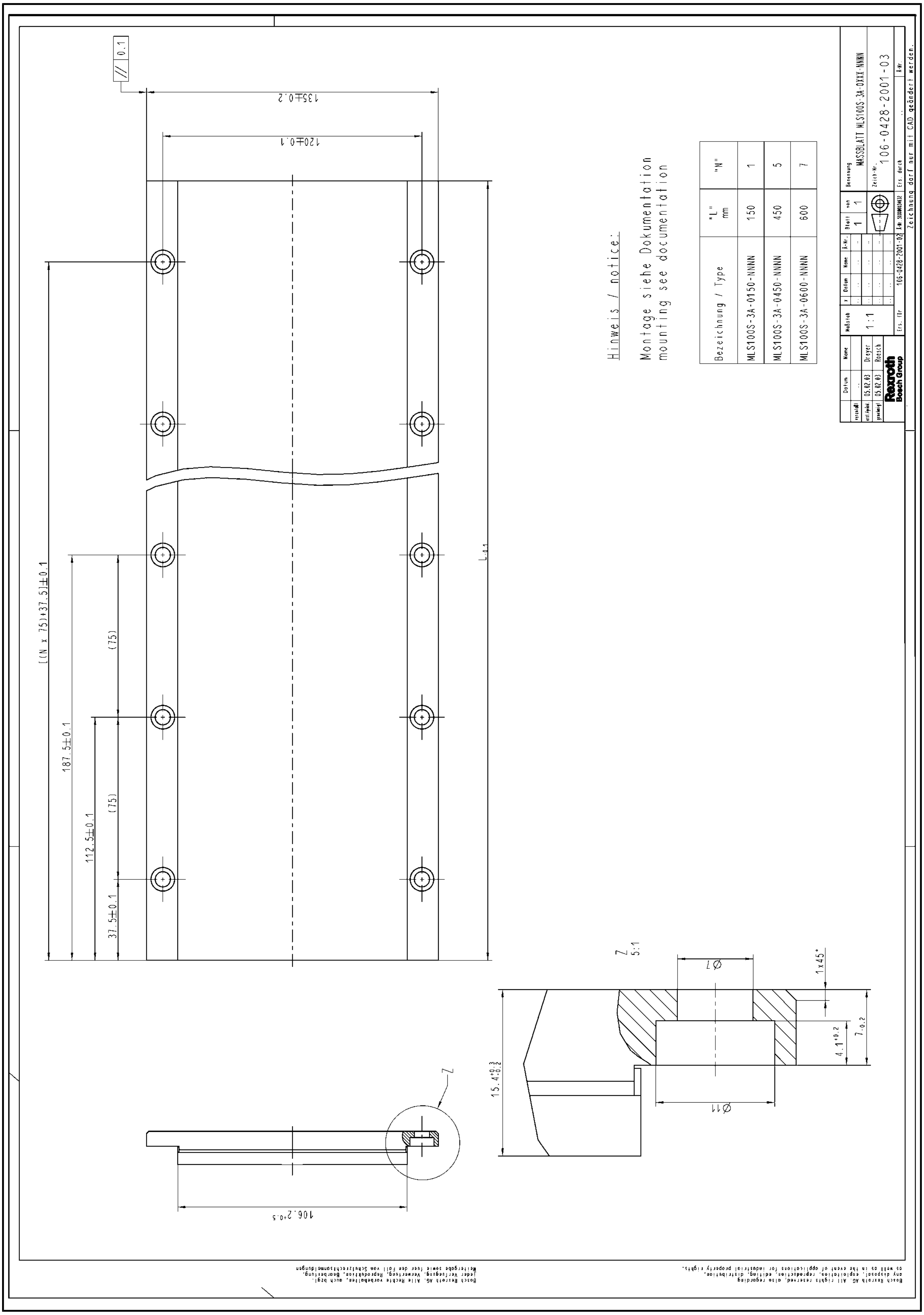
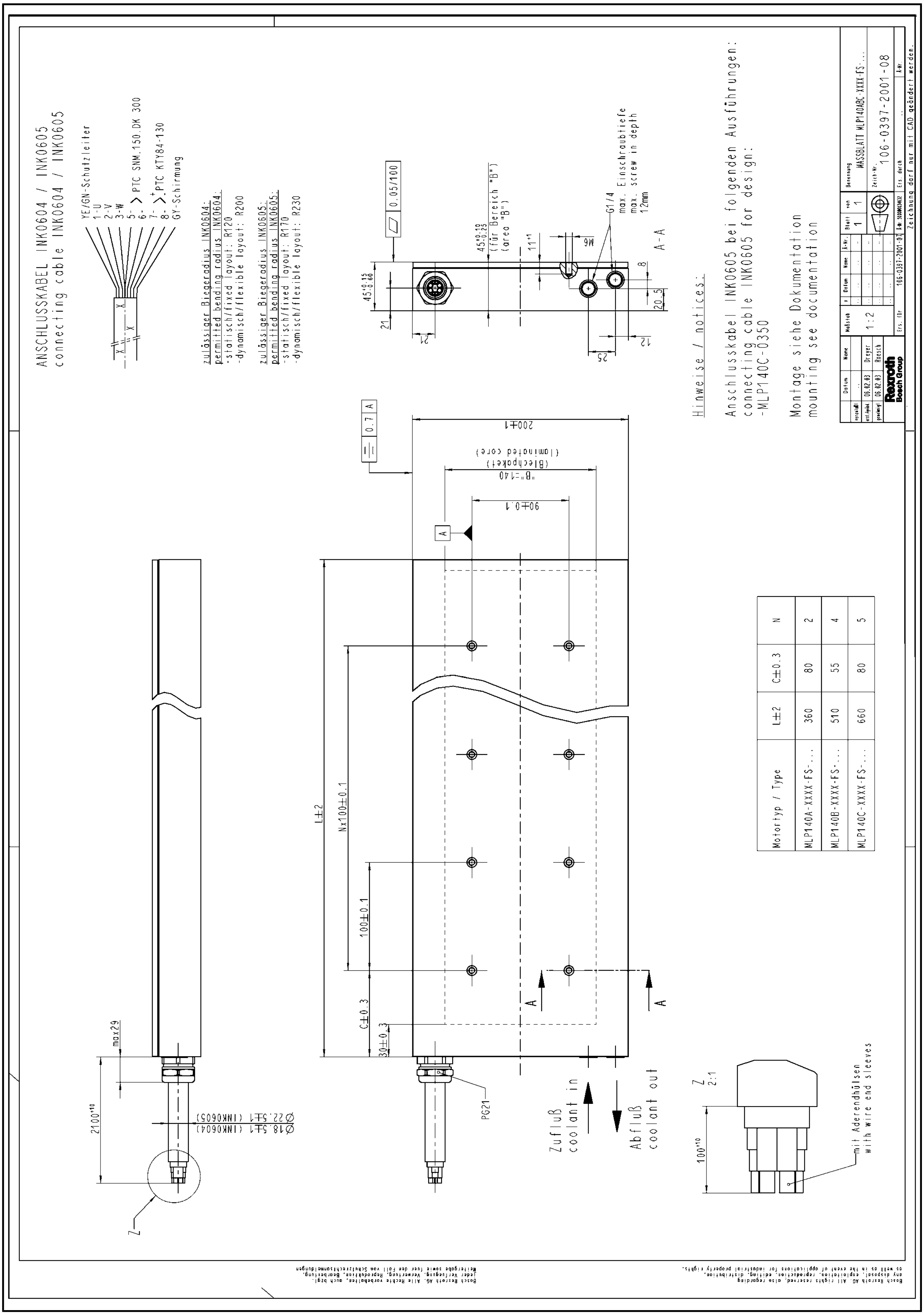



Fig.5-11: Secondary Part MLS100

# 5.5 Dimension Sheets Frame Size 140

## 5.5.1 Primary Part MLP140 with Standard Encapsulation



## 5.5.2 Primary Part MLP140 with Thermo Encapsulation

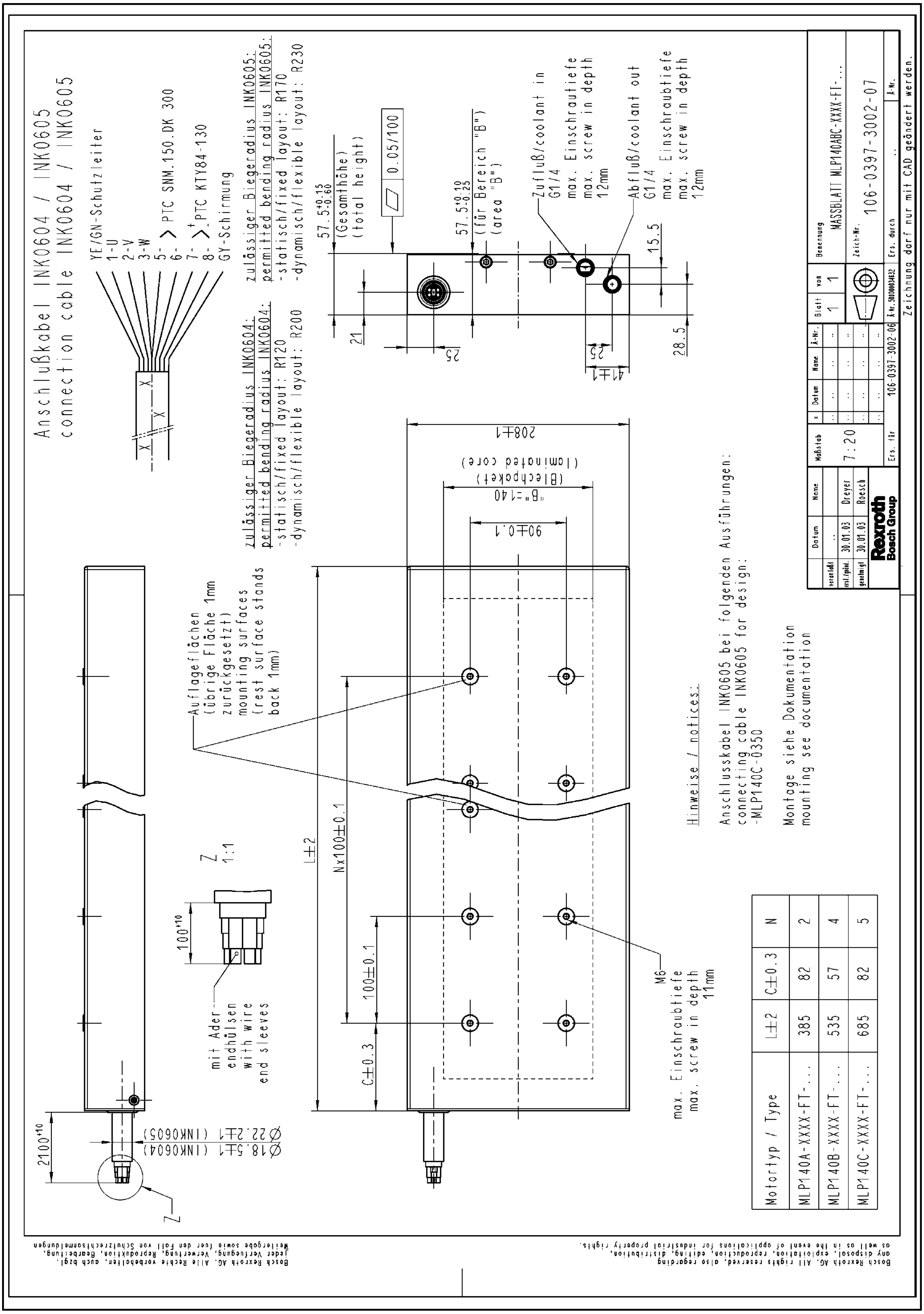



*Fig.5-13: Primary Part MLP140 with Thermo Encapsulation*

## 5.5.3 Secondary Part MLS140

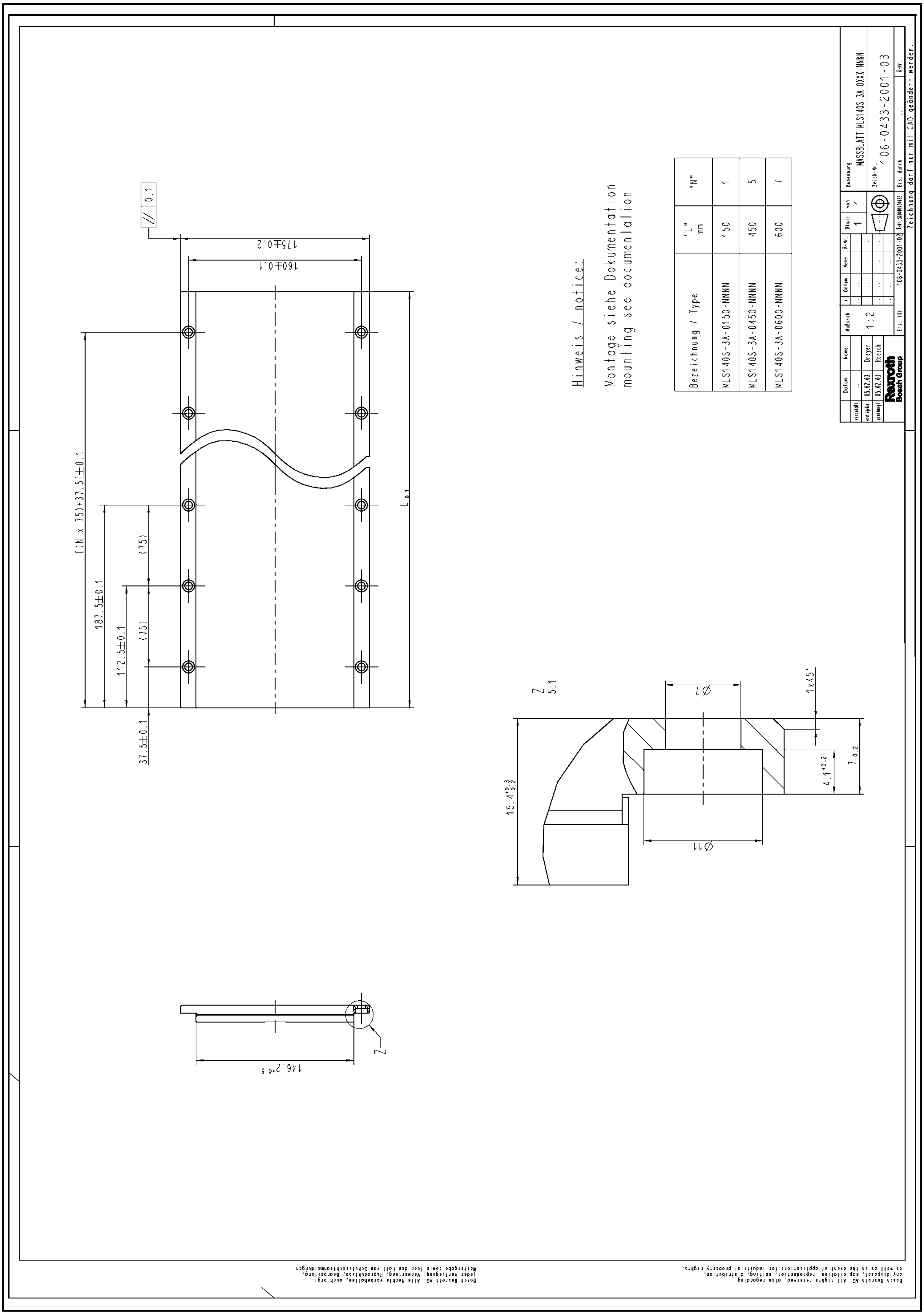
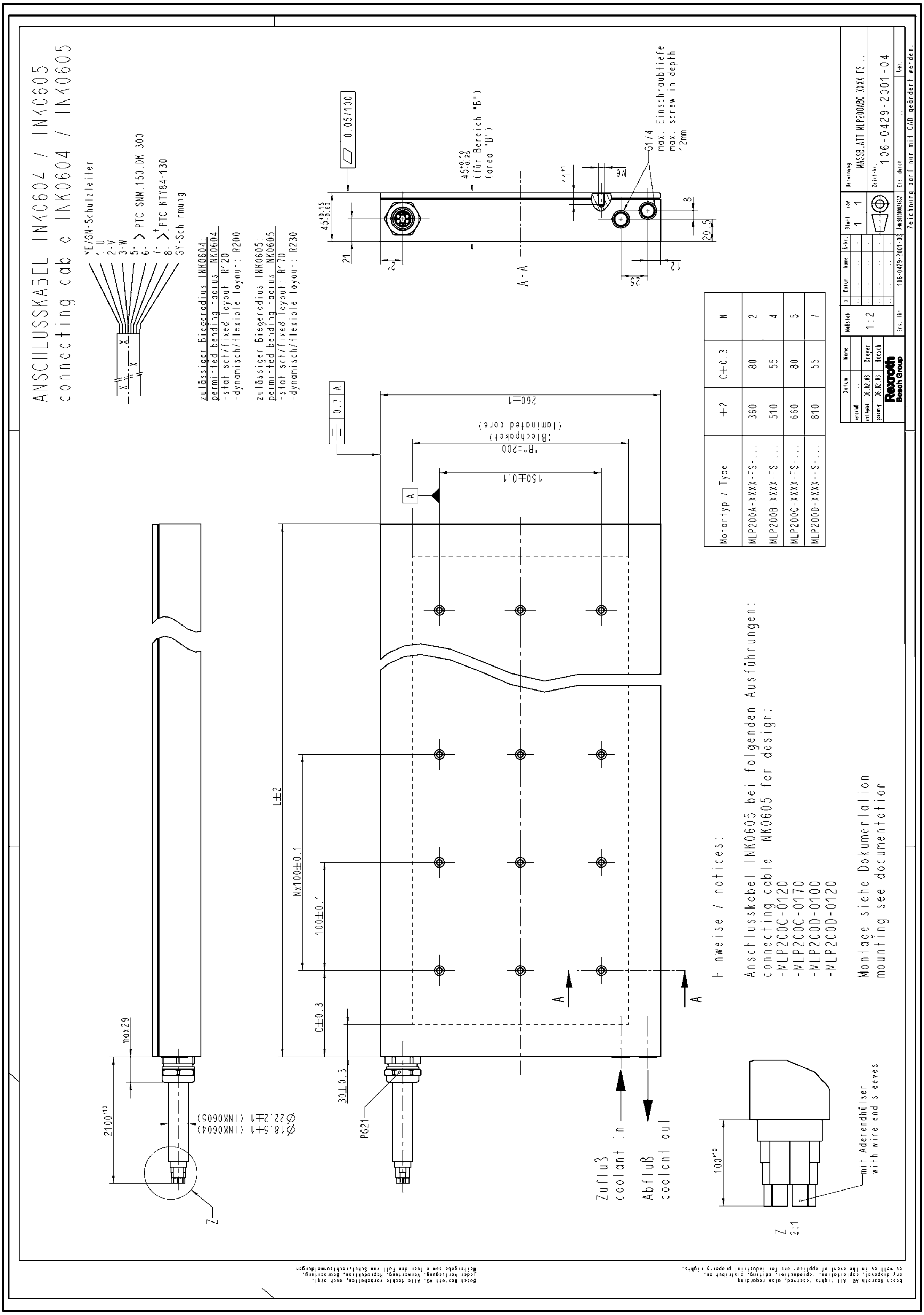


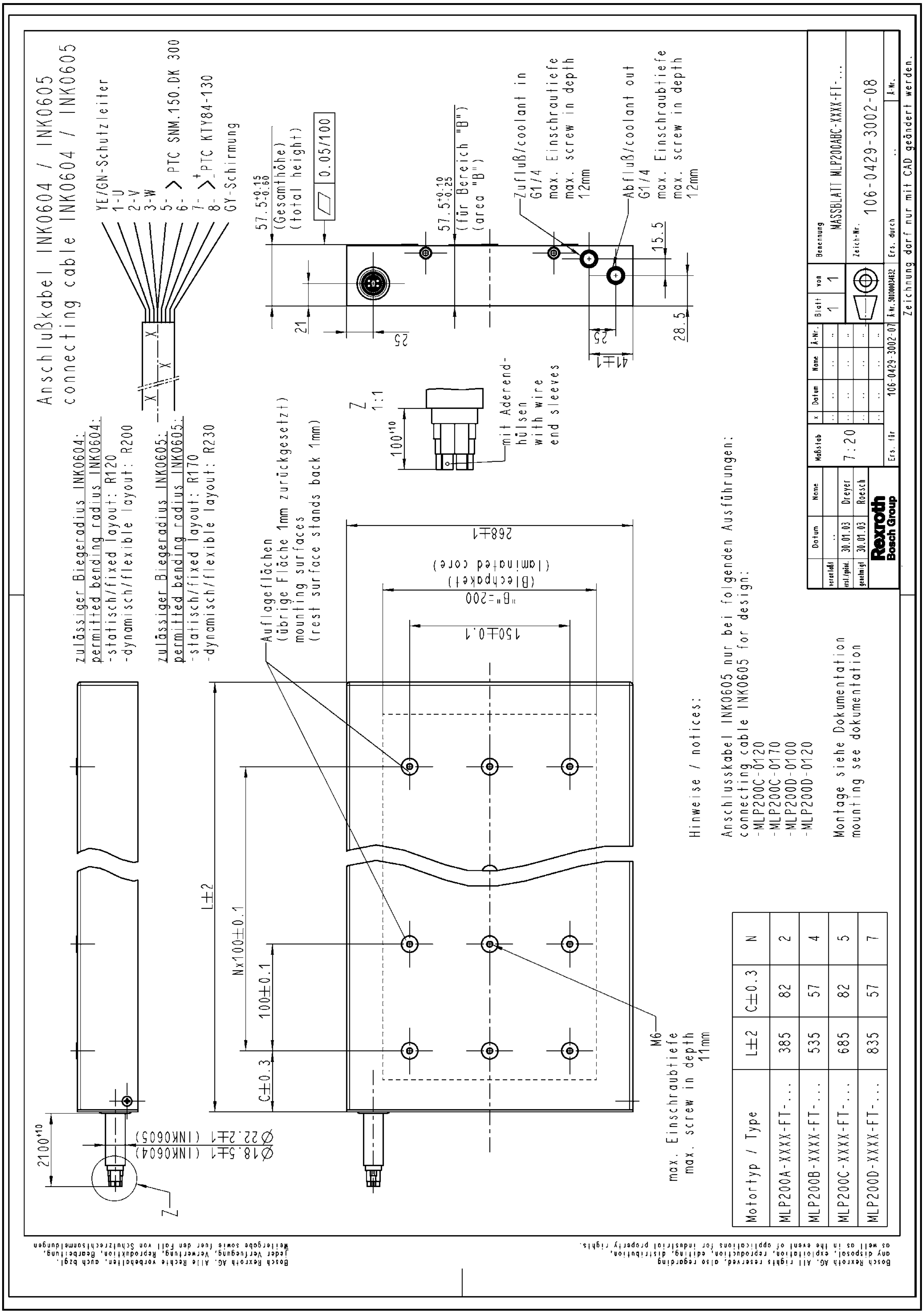

*Fig.5-14: Secondary Part MLS140*

# 5.6 Dimension Sheets Frame Size 200

## 5.6.1 Primary Part MLP200 with Standard Encapsulation



## 5.6.2 Primary Part MLP200 with Thermo Encapsulation




| Motortyp / Type | L±2 | C±0.3 | N |
|---|---|---|---|
| MLP200A-XXXX-FT-... | 385 | 82 | 2 |
| MLP200B-XXXX-FT-... | 535 | 57 | 4 |
| MLP200C-XXXX-FT-... | 685 | 82 | 5 |
| MLP200D-XXXX-FT-... | 835 | 57 | 7 |

*Fig.5-16: Primary Part MLP200 with Thermo Encapsulation*

## 5.6.3 Secondary Part MLS200

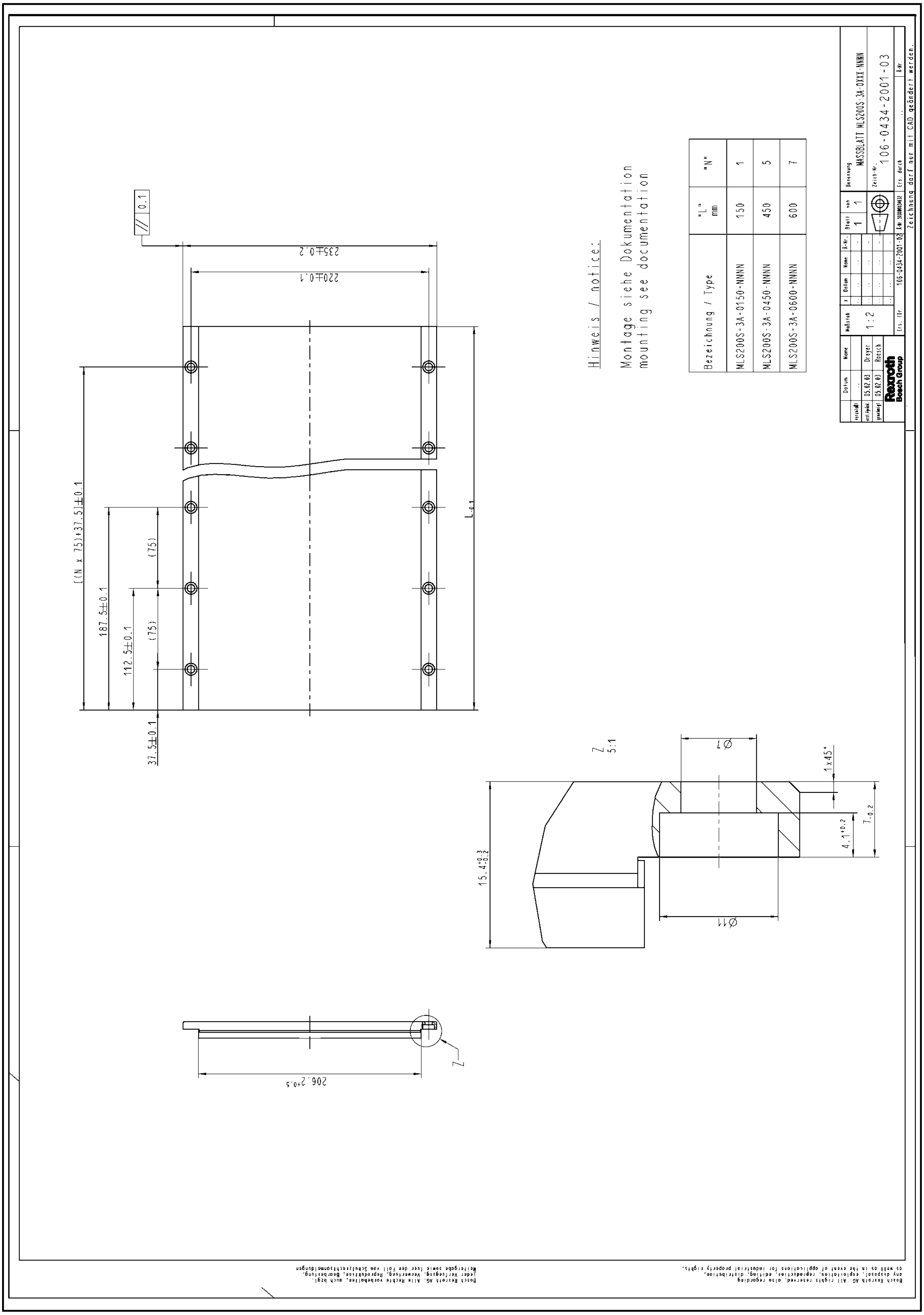
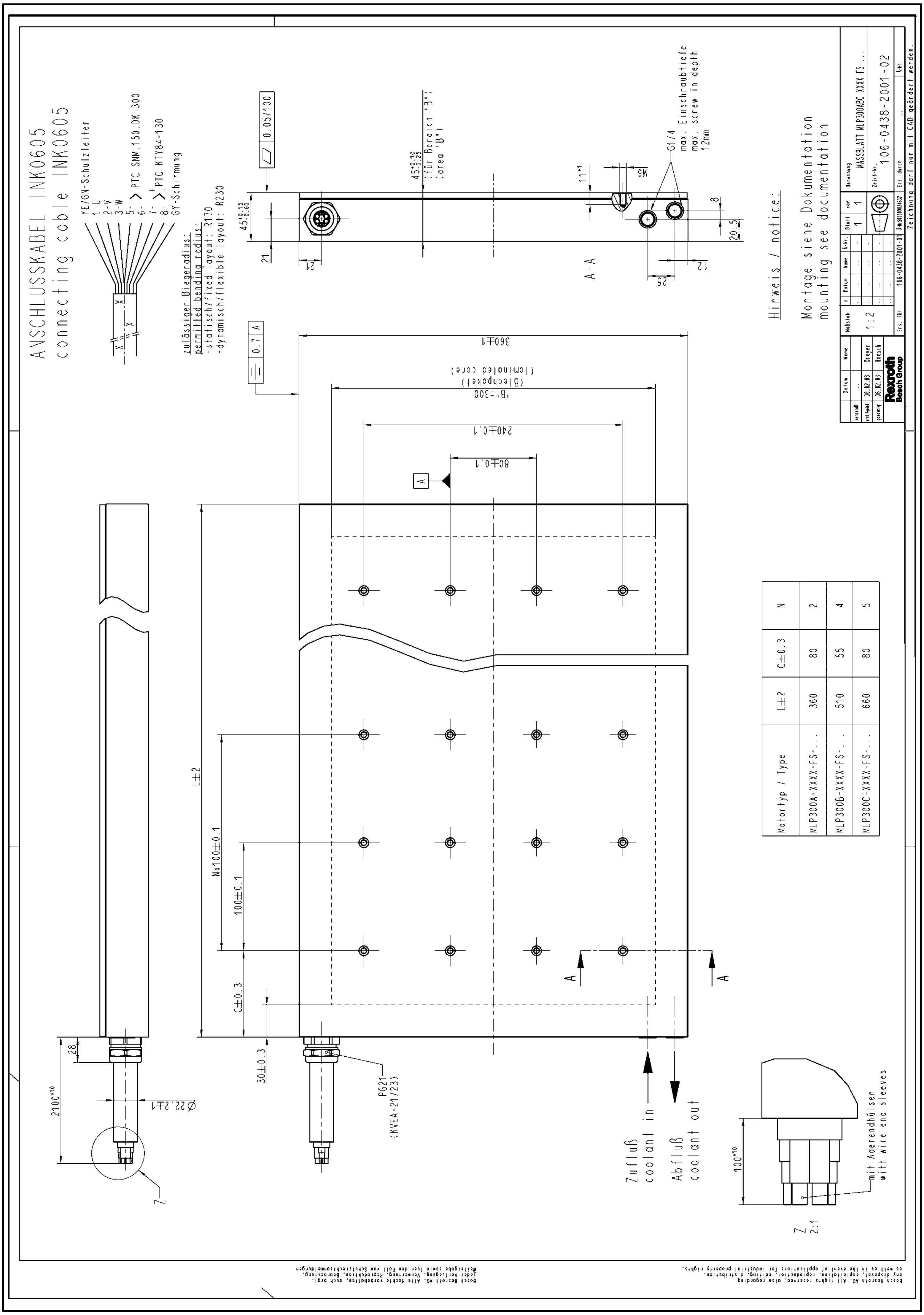


*Fig.5-17: Secondary Part MLS200*

# 5.7 Dimension Sheets Frame Size 300

## 5.7.1 Primary Part MLP300 with Standard Encapsulation



## 5.7.2 Primary Part MLP300 with Thermo Encapsulation

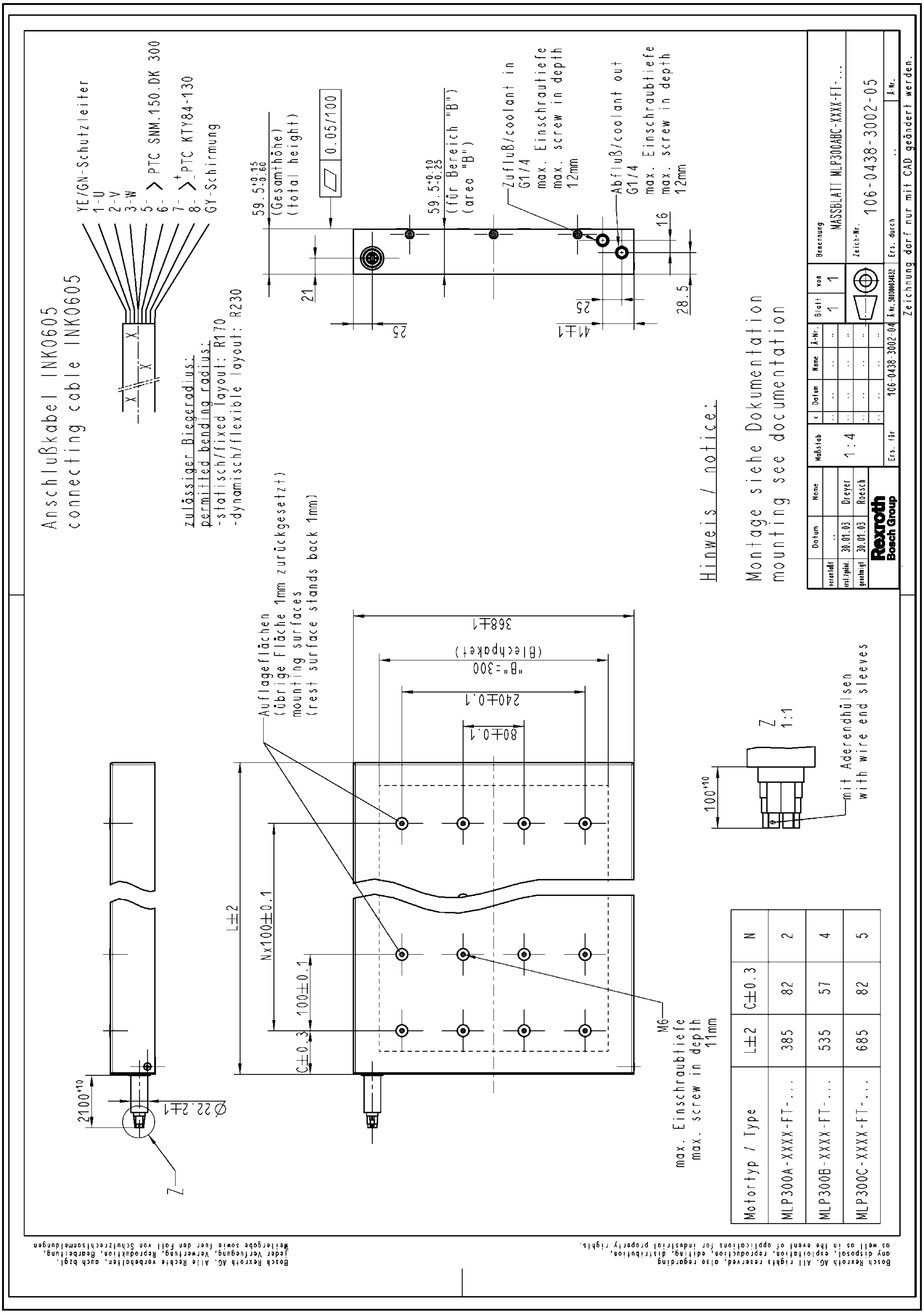



*Fig.5-19: Primary Part MLP300 with Thermo Encapsulation*

## 5.7.3 Secondary Part MLS300

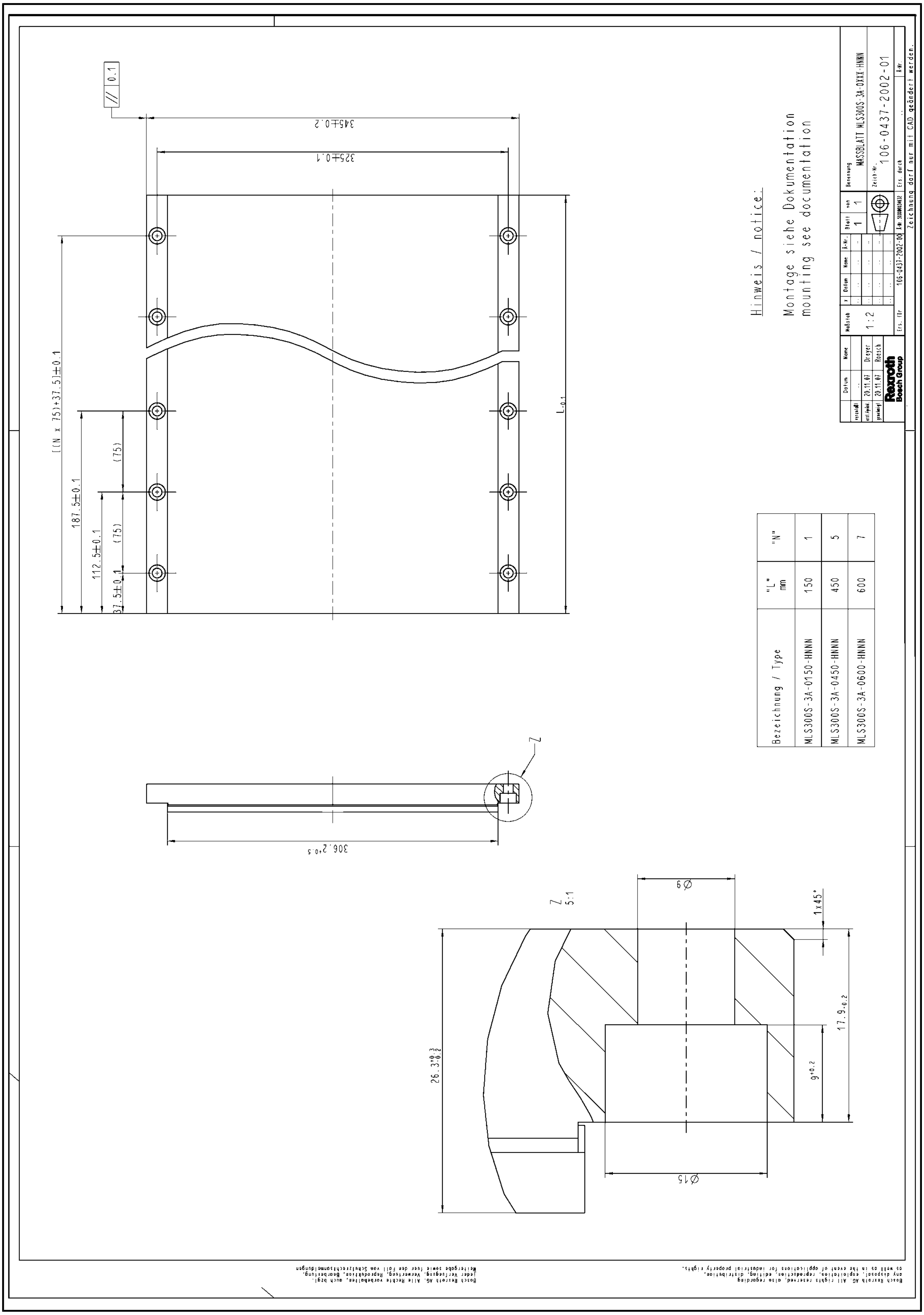



*Fig.5-20: Secondary Part MLS300*

# 6 Type Code IndraDyn L

## 6.1 Description

### 6.1.1 General Information

The type code describes the deliverable motor variants. It is the basis for selecting and ordering products from Bosch Rexroth. This applies to new products as well as to spare parts and repairs.

The overall product designation ”IndraDyn L” stands for synchronous linear motors. This designation describes the total system which consists of a primary and a secondary part. As linear motors are kit motors, the primary and secondary part obtain an additional, defined short term.

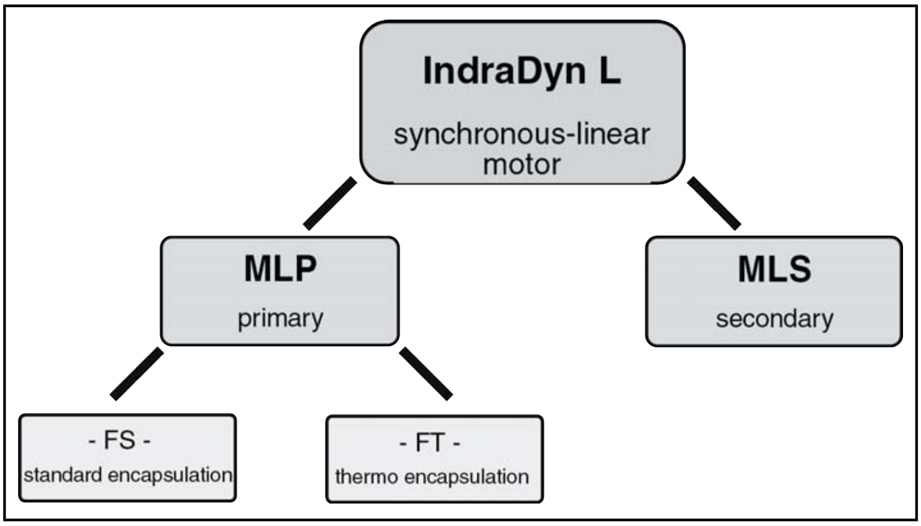



*Fig.6-1: Short term for IndraDyn L*

The following figures give an example of a motor type code for primary and secondary parts, by which an exact specification of the single parts (e.g. for orders) is possible.

The following description gives an overview over the separate columns of the type code (”abbrev. column”) and its meaning.

☞ When selecting a product, always consider the detailed specifications in the chapter 4 ”Technical Data” and chapter 9 ”Notes regarding Application”.

## 6.1.2 Type Code Primary Part MLP

### General Information

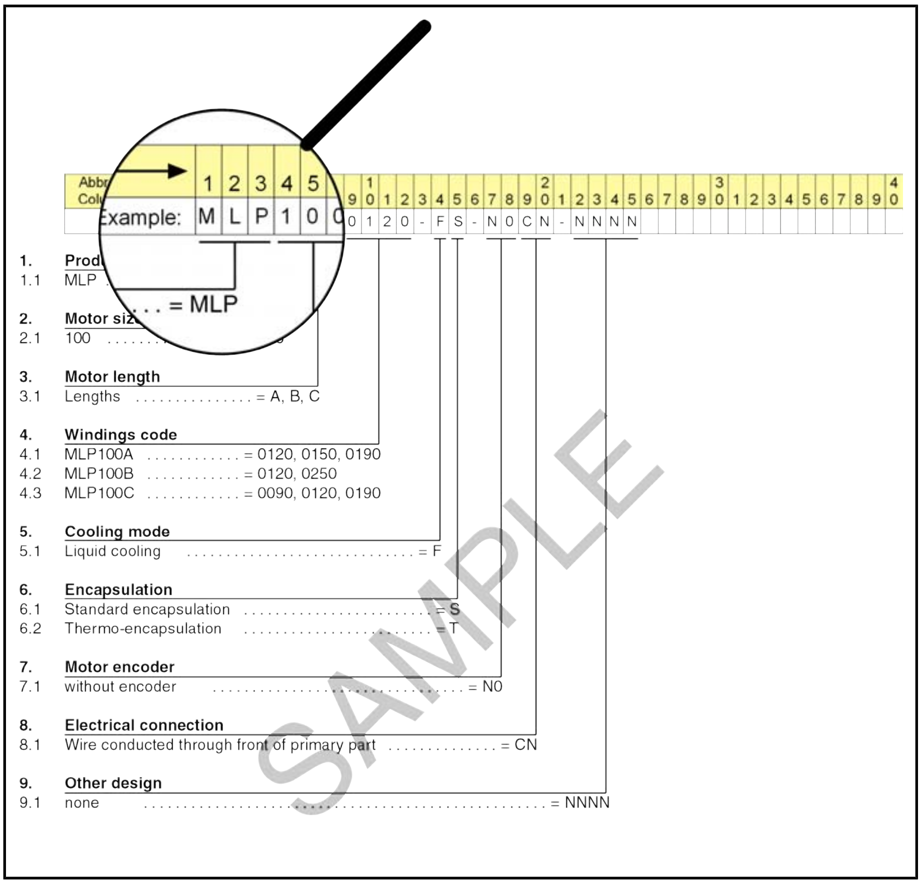



*Fig.6-2: Example for a type code primary part MLP100*

### Component MLP

**Abbrev. Column 123**

**MLP** is the designation of the primary part of an IndraDyn L motor.

### Motor frame size

**Abbrev. Column 456**

The motor frame size is derived from the active magnet width of the secondary part and representatives different power ranges.

### Motor Frame Length

**Abbrev. Column 7**

Within a series, the graduation of the increasing motor frame length is indicated by ID letters in alphabetic order.

Frame lengths are e.g. **A**, **B** or **C**.

### Winding Code

**Abbrev. Column 9 10 11 12**

The numbers of the winding code do also describe the reachable maximum speed $F_{max}$ in m/min.

### Cooling

**Abbrev. Column 14**

In general, the primary parts of the IndraDyn L motors are provided with **liquid cooling** for operation and thus only available with liquid cooling.

## Casing

**Abbrev. Column 15**

- **S= standard encapsulation**stainless steel encapsulation with a liquid cooling integrated into the back of the motor to dissipate the lost heat.
- **T = thermal encapsulation:**stainless steel encapsulation with an additional liquid cooling on the back of the motor and heat conductive plates for optimum thermal decoupling to the machine construction.

## Motor Encoder

**Abbrev. Column 1718**

The necessary length measuring system is not in the scope of delivery of Bosch Rexroth and has to be provided and mounted from the machine manufacturer himself.

## Electrical Connection

**Abbrev. Column 1920**

Primary parts of synchronous linear motors IndraDyn L are fitted with a high-flexible and shielded cable. The connection cable is brought out of the front of the primary part and is fixed with it.

## Other designs

**Abbrev. column 22 23 24 25**

Those fields are not reserved.

# 6.1.3 Type Code Secondary Part MLS

## General Information

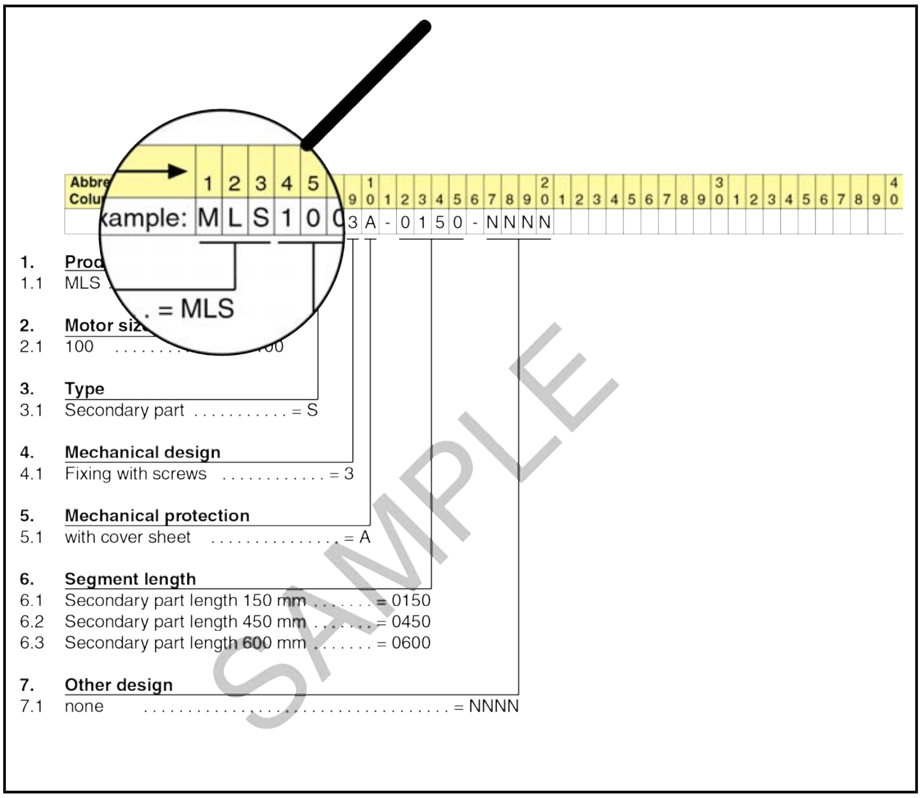



*Fig.6-3: Example for a type code secondary part MLS100*

## Component MLS

**Abbrev. Column 123**

**MLS** is the designation of the secondary part of an IndraDyn L motor.

## Motor frame size

**Abbrev. Column 456**

The motor frame size is derived from the active magnet width of the secondary part and representatives different power ranges.

## Type

**Abbrev. Column 7**

**S** = secondary part

## Mechanical Design

**Abbrev. Column 9**

The number **3** stands for the fastening of the secondary part with screws by fixing holes along the outer edge.

## Mechanical protection

**Abbrev. Column 10**

To ensure the utmost operation reliability, the permanent magnets of the secondary part are always protected against corrosion, action of outer influences (e.g. coolants and oil) and against mechanical damage, due to an integrated rustless cover plate.

## Segment length

**Abbrev. Column 12 13 14 15**

Secondary parts or - segments are available in the following lengths:

- 150mm
- 450mm
- 600mm

## Other designs

**Abbrev. Column 17 18 19 20**

**NNNN** = Those fields are not reserved.

**HNNN** = reinforced basic carrier (only for MLS300)

## 6.2 Type Code IndraDyn L Size 040

| Abbrev. Column | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Example: | M | L | P | 0 | 4 | 0 | A | - | 0 | 3 | 0 | 0 | - | F | S | - | N | 0 | C | N | - | N | N | N | N | | | | | | | | | | | | | | | |

**1. Product**
1.1 MLP. . . . . . . . = MLP

**2. Motor size**
2.1 040 . . . . . . . . . . . . . . = 040

**3. Motor length**
3.1 Lengths . . . . . . . . . . . . . . = A, B

**4. Windings code**
4.1 MLP040A. . . . . . . . . = 0300
4.2 MLP040B. . . . . . . . . = 0150, 0250, 0300

**5. Cooling mode**
5.1 Liquid cooling . . . . . . . . . . . . . . . . . . . . . . . = F

**6. Encapsulation**
6.1 Standard encapsulation . . . . . . . . . . . . . . . . . . = S
6.2 Thermo-encpsulation . . . . . . . . . . . . . . . . . . . . = T

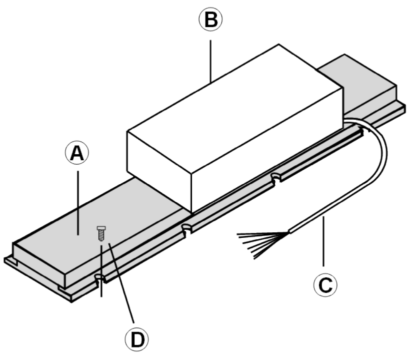
**7. Motor encoder**
7.1 without encoder. . . . . . . . . . . . . . . . . . . . . . . . . . = N0

**8. Electrical connection**
8.1 Wire conducted through front of primary part . . . . . . . . = CN

**9. Other design**
9.1 none . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . = NNNN

RNC-41430-401_NOR_N_D0_2003-08-06.fh11

**Illustration example:** MLP040




Ⓐ Secondary part MLS
Ⓑ Primary part MLP (Standard encapsulation or Thermo-encapsulation)
Ⓒ Electrical connection
Ⓓ Screw mounting (from above)

*Fig.6-4: Type code primary part MLP040*

Type Code IndraDyn L

| Abbrev. Column | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 20 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 30 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 40 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Example: | M | L | S | 0 | 4 | 0 | S | - | 3 | A | - | 0 | 1 | 5 | 0 | - | N | N | N | N | | | | | | | | | | | | | | | | | | | | |

**1. Product**
1.1 MLS . . . . . . . . = MLS

**2. Motor size**
2.1 040 . . . . . . . . . . . . . . = 040

**3. Type**
3.1 Secondary part . . . . . . . . . . . = S

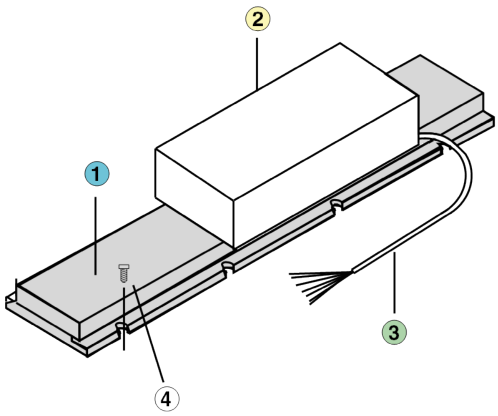
**4. Mechanical design**
4.1 Fixing with screws . . . . . . . . . . . . = 3

**5. Mechanical protection**
5.1 with cover sheet . . . . . . . . . . . . . . . = A

**6. Segment length**
6.1 Secondary part length 150 mm . . . . . . . = 0150
6.2 Secondary part length 450 mm . . . . . . . = 0450
6.3 Secondary part length 600 mm . . . . . . . = 0600

**7. Other design**
7.1 none . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . = NNNN

**Illustration example:** MLS040




1 Secondary part MLS
2 Primary part MLP (Standard encapsulation or Thermo-encapsulation)
3 Power connection
4 Screw mounting (from above)

*Fig.6-5: Type code secondary part MLS040*

## 6.3 Type Code IndraDyn L Size 070

| Abbrev. Column → | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 20 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 30 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 40 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Example: | M | L | P | 0 | 7 | 0 | A | - | 0 | 3 | 0 | 0 | - | F | T | - | N | 0 | C | N | - | N | N | N | N | | | | | | | | | | | | | | | |

**1. Product**
1.1 MLP . . . . . . . . . . = MLP

**2. Motor size**
2.1 070 . . . . . . . . . . . . . . . . . = 070

**3. Motor length**
3.1 Lengths . . . . . . . . . . . . . . . = A, B, C

**4. Windings code**
4.1 MLP070A = 0150, 0220, 0300
4.2 MLP070B = 0100, 0120, 0150, 0250, 0300
4.3 MLP070C = 0120, 0150, 0240, 0300

**5. Cooling mode**
5.1 Liquid cooling . . . . . . . . . . . . . . . . . . . . . . . . . . . . = F

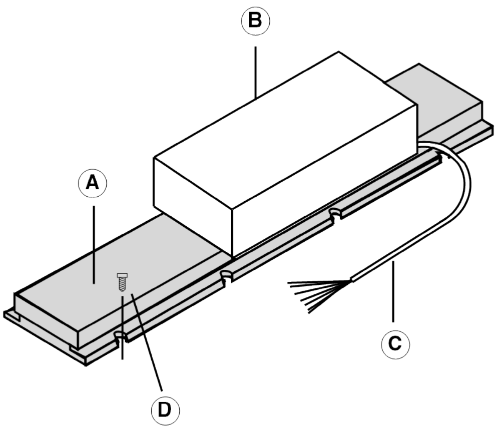
**6. Encapsulation**
6.1 Standard encapsulation . . . . . . . . . . . . . . . . . . . . . . . = S
6.2 Thermo-encapsulation . . . . . . . . . . . . . . . . . . . . . . . . = T

**7. Motor encoder**
7.1 without encoder . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . = N0

**8. Electrical connection**
8.1 Wire conducted through front of primary part . . . . . . . . . . . . . . = CN

**9. Other design**
9.1 none . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . = NNNN

**Illustration example:** MLP070




Ⓐ Secondary part MLS
Ⓑ Primary part MLP (Standard encapsulation or Thermo-encapsulation)
Ⓒ Electrical connection
Ⓓ Screw mounting (from above)

*Fig.6-6: Type code primary part MLP070*

Type Code IndraDyn L

| Abbrev. Column | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 20 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 30 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 40 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Example: | M | L | S | 0 | 7 | 0 | S | - | 3 | A | - | 0 | 1 | 5 | 0 | - | N | N | N | N | | | | | | | | | | | | | | | | | | | | |

**1. Product**
1.1 MLS . . . . . . . . = MLS

**2. Motor size**
2.1 070 . . . . . . . . . . . . . . = 070

**3. Type**
3.1 Secondary part . . . . . . . . . . = S

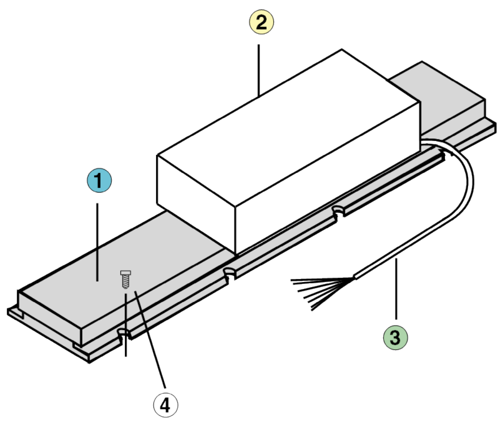
**4. Mechanical design**
4.1 Fixing with screws . . . . . . . . . . . . = 3

**5. Mechanical protection**
5.1 with cover sheet . . . . . . . . . . . . . . . = A

**6. Segment length**
6.1 Secondary part length 150 mm . . . . . . . = 0150
6.2 Secondary part length 450 mm . . . . . . . = 0450
6.3 Secondary part length 600 mm . . . . . . . = 0600

**7. Other design**
7.1 none . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . = NNNN

**Illustration example:** MLS070




1 Secondary part MLS
2 Primary part MLP (Standard encapsulation or Thermo-encapsulation)
3 Power connection
4 Screw mounting (from above)

*Fig.6-7: Type code secondary part MLS070*

## 6.4 Type Code IndraDyn L Size 100

| Abbrev. Column → | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 20 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 30 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 40 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Example: | M | L | P | 1 | 0 | 0 | A | - | 0 | 1 | 2 | 0 | - | F | S | - | N | 0 | C | N | - | N | N | N | N | | | | | | | | | | | | | | | |

1. Product
1.1 MLP . . . . . . . . . . = MLP

2. Motor size
2.1 100 . . . . . . . . . . . . . . . . . = 100

3. Motor length
3.1 Lengths . . . . . . . . . . . . . . . = A, B, C

4. Windings code
4.1 MLP100A . . . . . . . = 0090, 0120, 0150, 0190
4.2 MLP100B . . . . . . . = 0120, 0250
4.3 MLP100C . . . . . . . = 0090, 0120, 0190

5. Cooling mode
5.1 Liquid cooling . . . . . . . . . . . . . . . . . . . . . . . . . . . . . = F

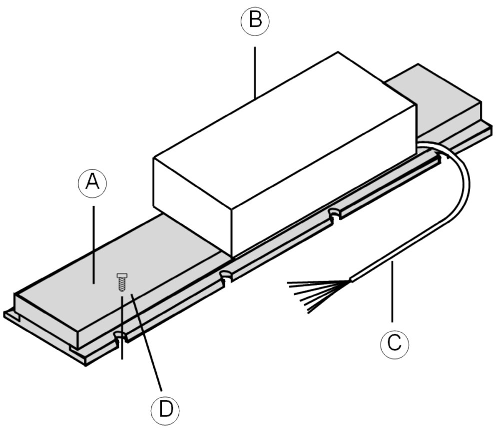
6. Encapsulation
6.1 Standard encapsulation . . . . . . . . . . . . . . . . . . . . . . . . = S
6.2 Thermo-encapsulation . . . . . . . . . . . . . . . . . . . . . . . . = T

7. Motor encoder
7.1 without encoder . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . = N0

8. Electrical connection
8.1 Wire conducted through front of primary part . . . . . . . . . . . . . . . = CN

9. Other design
9.1 none . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . =NNNN

Illustration example: MLP100




Ⓐ Secondary part MLS
Ⓑ Primary part MLP (Standard encapsulation or Thermo-encapsulation)
Ⓒ Electrical connection
Ⓓ Screw mounting (from above)

*Fig.6-8: Type code primary part MLP100*

Type Code IndraDyn L

| Abbrev. Column | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Example: | M | L | S | 1 | 0 | 0 | S | - | 3 | A | - | 0 | 1 | 5 | 0 | - | N | N | N | N | | | | | | | | | | | | | | | | | | | | |

**1. Product**
1.1 MLS . . . . . . . . = MLS

**2. Motor size**
2.1 100 . . . . . . . . . . . . . . = 100

**3. Type**
3.1 Secondary part . . . . . . . . . . . = S

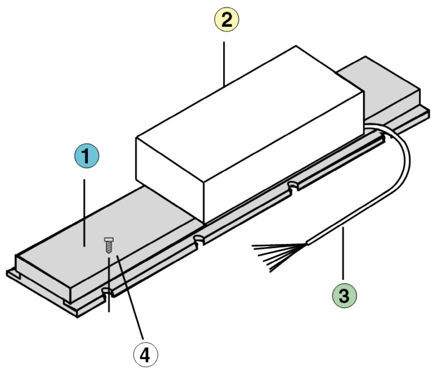
**4. Mechanical design**
4.1 Fixing with screws . . . . . . . . . . . . = 3

**5. Mechanical protection**
5.1 with cover sheet . . . . . . . . . . . . . . . = A

**6. Segment length**
6.1 Secondary part length 150 mm . . . . . . . = 0150
6.2 Secondary part length 450 mm . . . . . . . = 0450
6.3 Secondary part length 600 mm . . . . . . . = 0600

**7. Other design**
7.1 none . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . = NNNN

**Illustration example:** MLS100




① Secondary part MLS
② Primary part MLP (Standard encapsulation or Thermo-encapsulation)
③ Power connection
④ Screw mounting (from above)

*Fig.6-9: Type code secondary part MLS100*

# 6.5 Type Code IndraDyn L Size 140

| Abbrev. Column → | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 20 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 30 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 40 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Example: | M | L | P | 1 | 4 | 0 | C | - | 0 | 0 | 5 | 0 | - | F | T | - | N | 0 | C | N | - | N | N | N | N | | | | | | | | | | | | | | | |

**1. Product**
1.1 MLP . . . . . . . . = MLP

**2. Size**
2.1 140 . . . . . . . . . . . . . . = 140

**3. Length**
3.1 Lengths . . . . . . . . . . . . = A, B, C

**4. Winding**
4.1 MLP140A . . . = 0120
4.2 MLP140B . . . = 0090, 0120
4.3 MLP140C . . . = 0050, 0120, 0170, 0350

**5. Cooling**
5.1 Liquid cooling . . . . . . . . . . . . . . . . . . . . . . . . = F

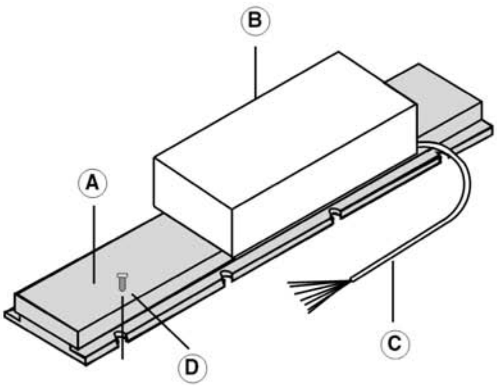
**6. Encapsulation**
6.1 Standard encapsulation . . . . . . . . . . . . . . . . . . = S
6.2 Thermo encapsulation . . . . . . . . . . . . . . . . . . . = T

**7. Encoder**
7.1 without encoder . . . . . . . . . . . . . . . . . . . . . . . . . . . = N0

**8. Electrical connection**
8.1 wire conducted through front of primary part . . . . . . . . = CN

**9. Other design**
9.1 none . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . = NNNN

**Illustration example:** MLP140




(A) Secondary part MLS
(B) Primary part MLP (Standard encapsulation or Thermo encapsulation)
(C) Electrical connection
(D) Screw mounting (from above)

*Fig.6-10: Type code primary part MLP140*

Type Code IndraDyn L

| Abbrev. Column | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 20 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 30 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 40 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Example: | M | L | S | 1 | 4 | 0 | S | - | 3 | A | - | 0 | 1 | 5 | 0 | - | N | N | N | N | | | | | | | | | | | | | | | | | | | | |

**1. Product**
1.1 MLS . . . . . . . . = MLS

**2. Motor size**
2.1 140 . . . . . . . . . . . . . . . = 140

**3. Type**
3.1 Secondary part . . . . . . . . . . = S

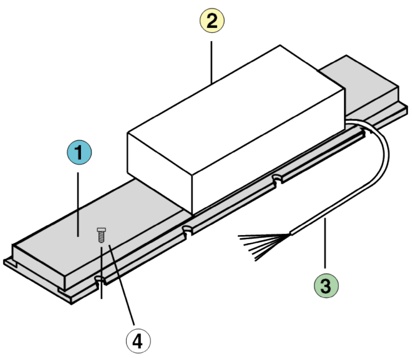
**4. Mechanical design**
4.1 Fixing with screws . . . . . . . . . . . . = 3

**5. Mechanical protection**
5.1 with cover sheet . . . . . . . . . . . . . . . = A

**6. Segment length**
6.1 Secondary part length 150 mm . . . . . . . = 0150
6.2 Secondary part length 450 mm . . . . . . . = 0450
6.3 Secondary part length 600 mm . . . . . . . = 0600

**7. Other design**
7.1 none . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . = NNNN

**Illustration example:** MLS140




1 Secondary part MLS
2 Primary part MLP (Standard encapsulation or Thermo-encapsulation)
3 Power connection
4 Screw mounting (from above)

*Fig.6-11: Type code secondary part MLS140*

# 6.6 Type Code IndraDyn L Size 200

| Abbrev. Column | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 20 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 30 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 40 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Example: | M | L | P | 2 | 0 | 0 | A | - | 0 | 1 | 2 | 0 | - | F | S | - | N | 0 | C | N | - | N | N | N | N | | | | | | | | | | | | | | | |

**1. Product**
1.1 MLP . . . . . . . . . . = MLP

**2. Motor size**
2.1 200 . . . . . . . . . . . . . . . . . = 200

**3. Motor length**
3.1 Lengths . . . . . . . . . . . . . = A, B, C, D

**4. Windings code**
4.1 MLP200A . . . . . . . . . . . . = 0090, 0120
4.2 MLP200B . . . . . . . . . . . . = 0040, 0120
4.3 MLP200C . . . . . . . . . . . . = 0090, 0120, 0170
4.4 MLP200D . . . . . . . . . . . . = 0060, 0100, 0120

**5. Cooling mode**
5.1 Liquid cooling . . . . . . . . . . . . . . . . . . . . . . . . . . . . = F

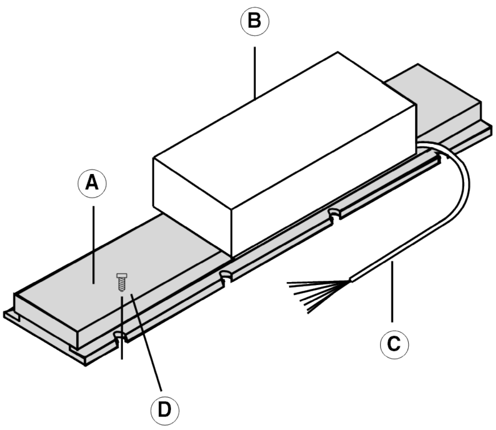
**6. Encapsulation**
6.1 Standard encapsulation . . . . . . . . . . . . . . . . . . . . . . . = S
6.2 Thermo-encapsulation . . . . . . . . . . . . . . . . . . . . . . . . = T

**7. Motor encoder**
7.1 without encoder . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . = N0

**8. Electrical connection**
8.1 Wire conducted through front of primary part . . . . . . . . . . . . . . = CN

**9. Other design**
9.1 none . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . = NNNN

**Illustration example:** MLP200




Ⓐ Secondary part MLS
Ⓑ Primary part MLP (Standard encapsulation or Thermo-encapsulation)
Ⓒ Electrical connection
Ⓓ Screw mounting (from above)

*Fig.6-12: Type code primary part MLP200*

Type Code IndraDyn L

| Abbrev. Column | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 20 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 30 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 40 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Example: | M | L | S | 2 | 0 | 0 | S | - | 3 | A | - | 0 | 1 | 5 | 0 | - | N | N | N | N | | | | | | | | | | | | | | | | | | | | |

**1. Product**

1.1 MLS . . . . . . . . . = MLS

**2. Motor size**

2.1 200 . . . . . . . . . . . . . . . = 200

**3. Type**

3.1 Secondary part . . . . . . . . . . . = S

**4. Mechanical design**

4.1 Fixing with screws . . . . . . . . . . . . = 3

**5. Mechanical protection**

5.1 with cover sheet . . . . . . . . . . . . . . . . = A

**6. Segment length**

6.1 Secondary part length 150 mm . . . . . . . = 0150

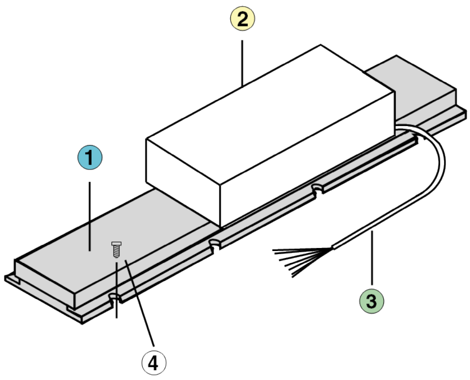
6.2 Secondary part length 450 mm . . . . . . . = 0450

6.3 Secondary part length 600 mm . . . . . . . = 0600

**7. Other design**

7.1 none . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . = NNNN

**Illustration example:** MLS200




1 Secondary part MLS
2 Primary part MLP (Standard encapsulation or Thermo-encapsulation)
3 Power connection
4 Screw mounting (from above)

*Fig.6-13: Type code secondary part MLS200*

# 6.7 Type Code IndraDyn L Size 300

| Abbrev. Column | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 20 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 30 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 40 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Example: | M | L | P | 3 | 0 | 0 | B | - | 0 | 1 | 2 | 0 | - | F | T | - | N | 0 | C | N | - | N | N | N | N | | | | | | | | | | | | | | | |

**1. Product**
1.1 MLP . . . . . . . . . . = MLP

**2. Motor size**
2.1 300 . . . . . . . . . . . . . . . . . = 300

**3. Motor length**
3.1 Lengths . . . . . . . . . . . . . . . = A, B, C

**4. Windings code**
4.1 MLP300A . . . . . . . . . . . . . . . . . = 0090, 0120
4.2 MLP300B . . . . . . . . . . . . . . . . . = 0070, 0120
4.3 MLP300C . . . . . . . . . . . . . . . . . = 0060, 0090

**5. Cooling**
5.1 Liquid cooling . . . . . . . . . . . . . . . . . . . . . . . . . . . . = F

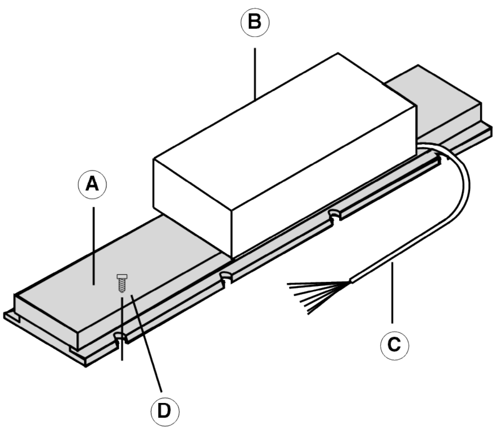
**6. Encapsulation**
6.1 Thermo-encapsulation . . . . . . . . . . . . . . . . . . . . . . . . = T

**7. Motor encoder**
7.1 without encoder . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . = N0

**8. Electrical connection**
8.1 Cable conducted through front of the primary part . . . . . . . . . . = CN

**9. Other design**
9.1 none . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . = NNNN

**Illustration example:** MLP300




Ⓐ Secondary part MLS
Ⓑ Primary part MLP (Standard encapsulation or Thermo-encapsulation)
Ⓒ Electrical connection
Ⓓ Screw mounting (from above)

*Fig.6-14: Type code primary part MLP300*

Type Code IndraDyn L

| **Abbrev. Column** → | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 20 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 30 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 40 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Example: | M | L | S | 3 | 0 | 0 | S | - | 3 | A | - | 0 | 1 | 5 | 0 | - | H | N | N | N | | | | | | | | | | | | | | | | | | | | |

**Product**
MLS. . . . . . . . = MLS

**Size**
300 . . . . . . . . . . . . . . . = 300

**Type**
Secondary part . . . . . . . . . . = S

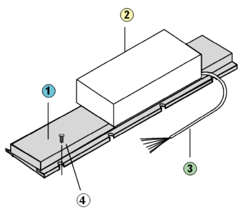
**Mechanical design**
Fixing per screws . . . . . . . . . . . . = 3

**Mechanical protection**
With cover sheet . . . . . . . . . . . . . . = A

**Segment length**
Secondary part length 150 mm. . . . . . . = 0150
Secondary part length 450 mm. . . . . . . = 0450
Secondary part length 600 mm. . . . . . . = 0600

**Other design**
Reinforced basic carrier . . . . . . . . . . . . . . . . . . . . = HNNN

**Illustration example:** MLS300




1. Secondary part MLS
2. Primary part MLP (Standard encapsulation or Thermo-encapsulation)
3. Power connection
4. Screw mounting (from above)

*Fig.6-15: Type code secondary part MLS200*

# 7 Accessories and Options

## 7.1 Hall Sensor Box

### 7.1.1 General Information

The Hall sensor box SHL is an optional component for drive controllers with incremental measuring systems and IndraDyn L motors of Bosch Rexroth.

When using an incremental length measuring system a commutation of the axes has to result from every step up of the phases of the drive device. This results from an drive-internal procedure. After this, a force processing of the motor is possible.

☞ The commutation is determined automatically during the phase step up by the Hall sensor box. Therefore, no power switch-on is necessary.

Possible applications are, for example

- Commutation of motor on vertically axes,
- Commutation of motors which should not move for safety reasons during the commutation process .
- Gantry-arrangement of the motors.

Delivery of the Hall sensor boxes as accessory can be made alternatively

- ex works, as accessory of an IndraDyn L motor,
- as single part for retrofitting of existing machines with IndraDyn or Eco-drive drive controllers and IndraDyn L motors.

☞ With the appropriate firmware are also control units of the type Diax compatible with the hall sensor boxes of type SHL.

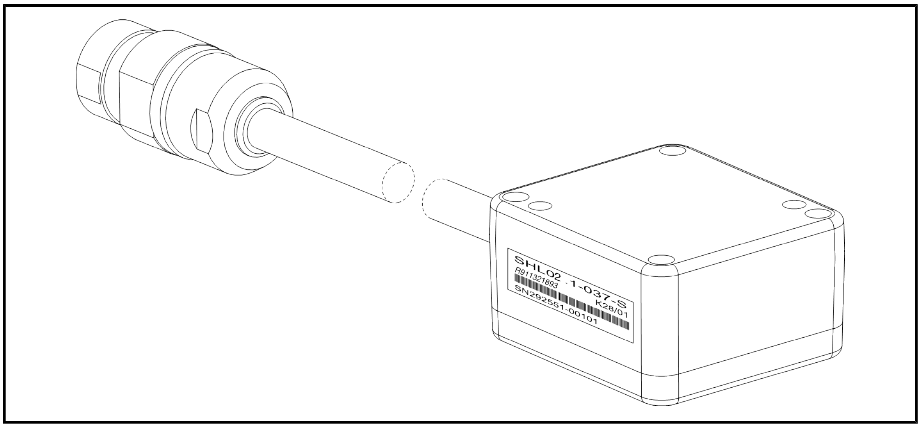
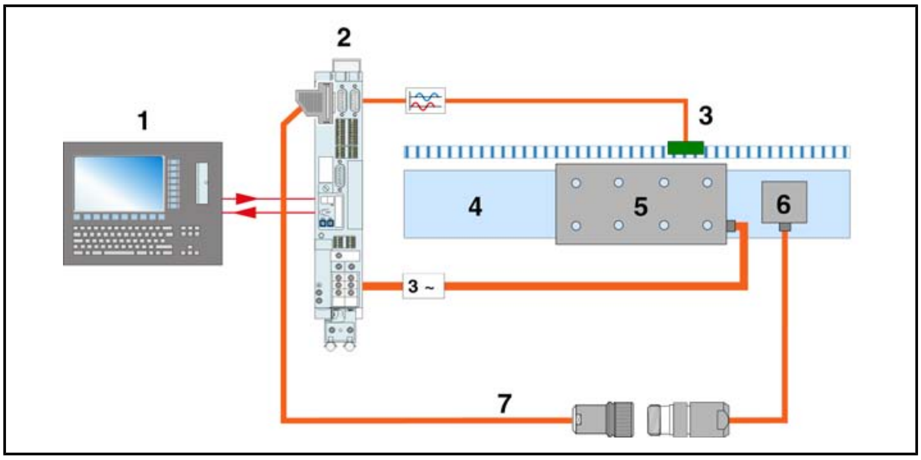



*Fig.7-1: Accessory Hall sensor box SHL*

## 7.1.2 Schematic Assembly




| | |
|---|---|
| 1 | Control unit |
| 2 | Control device |
| 3 | Linear scale |
| 4 | Secondary part |
| 5 | Primary part |
| 6 | Hall sensor box with cable |
| *Fig.7-2:* | *Schematic installation IndraDyn L with Hall sensor box* |

☞ Heed the notes regarding "Hall sensor box SHL" in the functional description of the documentation.

- MNR R911306588 (German)
- MNR R911292537 (English)

# 8 Electrical Connection

## 8.1 Power Connection

### 8.1.1 Power Cable on the Primary Part

Primary parts of IndraDyn L motors are fitted with a flexible and shielded power cable. This power cable is connected with the primary part and is 2m long.

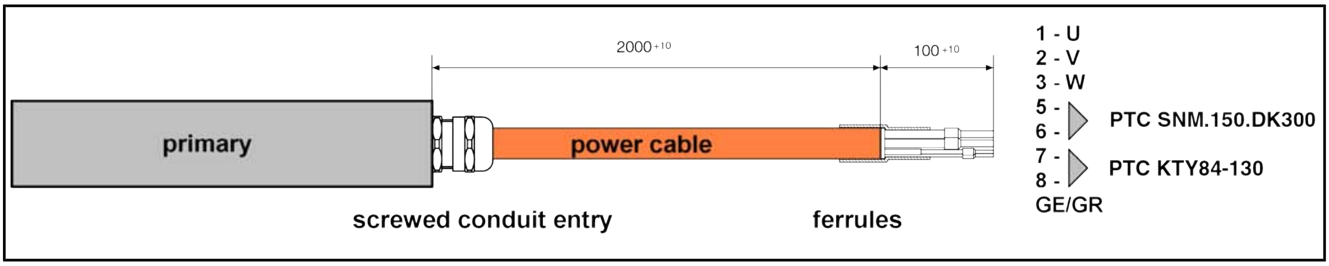



*Fig.8-1: Design of power cable on the primary part MLP*

The following overview gives the technical data of the power cables for every single motor size.

<table>
<tr><th>Motor frame size</th><th>Power cable on the primary part</th><th>Cross-section Power wires</th><th>Cross-section Control wire</th><th>Cross-section</th><th>Bending radius statically</th></tr>
<tr><td>MLP040x-xxxx</td><td>INK653</td><td>1.0 mm²</td><td>0.75 mm²</td><td>12 mm</td><td>72 mm</td></tr>
<tr><td>MLP070x-xxxx</td><td>INK603</td><td>4.0 mm²</td><td rowspan="3">1,0<br>or<br>1.5 mm²</td><td>16.3 mm</td><td>100 mm</td></tr>
<tr><td>MLP100x-xxxx<br>MLP140A-xxxx<br>MLP140B-xxxx<br>MLP140C-0050<br>MLP140C-0120<br>MLP140C-0170<br>MLP200A-xxxx<br>MLP200B-xxxx<br>MLP200C-0090<br>MLP200D-0060</td><td>INK604</td><td>6.0 mm²</td><td>18.5 mm</td><td>110 mm</td></tr>
<tr><td>MLP140C-0350<br>MLP200C-0120<br>MLP200C-0170<br>MLP200D-0100<br>MLP200D-0120<br>MLP300x-xxxx</td><td>INK605</td><td>10.0 mm²</td><td>22.2 mm</td><td>130 mm</td></tr>
</table>

*Fig.8-2: Power cable on the primary part MLP*

**Passing the power cable**

The power cable, which is connected to the primary part, ends with open wire end, provided with wire end ferrules (see fig. 8-1 "Design of power cable on the primary part MLP" on page 87) and might never be abandoned to dynamic bending forces. A passing of the primary part cable should thus never be made in a moving drag chain.

We recommend to assembly the cable in fixed passing to

- a flange socket
- a coupling or
- a terminal box (not in the scope of delivery of Rexroth).

From this junction, the power supply with the connection cable can be laid through a drag chain, resp. the machine construction. Ready-made connection cables are available from Rexroth.

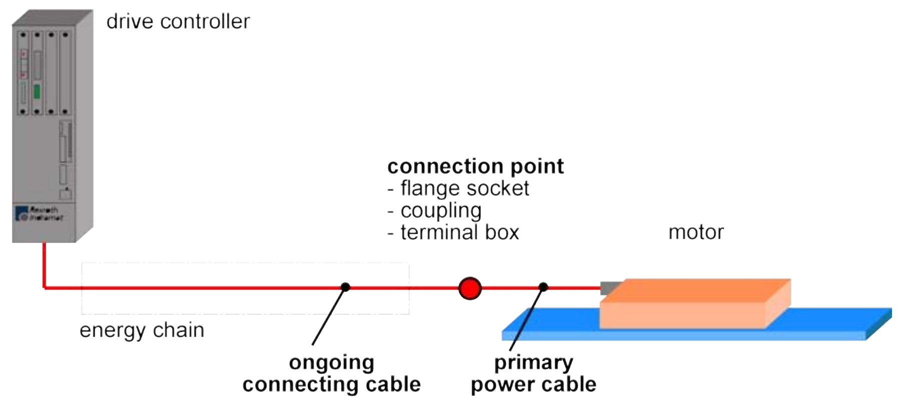



*Fig.8-3: Passing the connection cable of the primary part*

**WARNING**

**Damage of the connection cable and thus of the motor by dynamic bending forces!**

⇒ No passing of the primary part-cable in a drag chain.

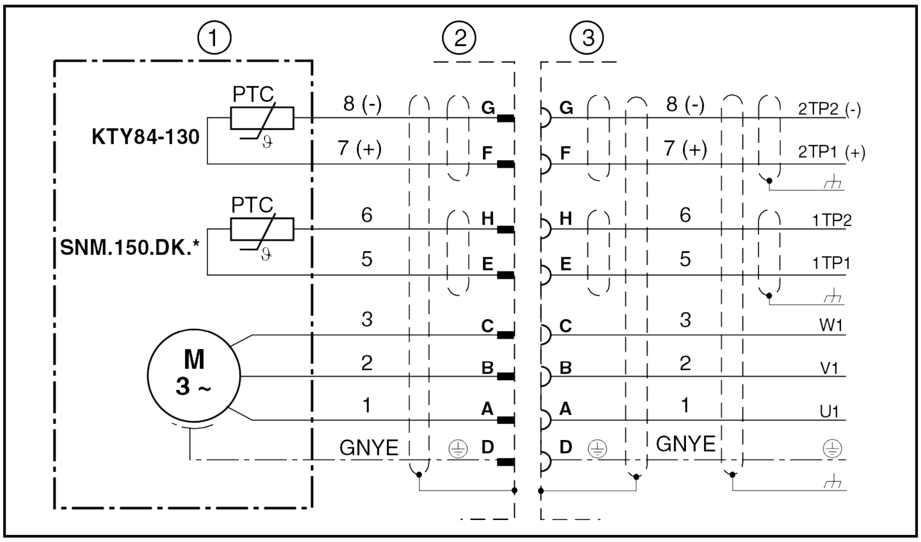
⇒ Passing the connection cable after the junction into a drag chain.

☞ The power cables of the primary part are designed for the highest voltage of a motor size. The cross-section of a power cable can, in any circumstances, be smaller.

# 8.1.2 Connection power supply

## General Information

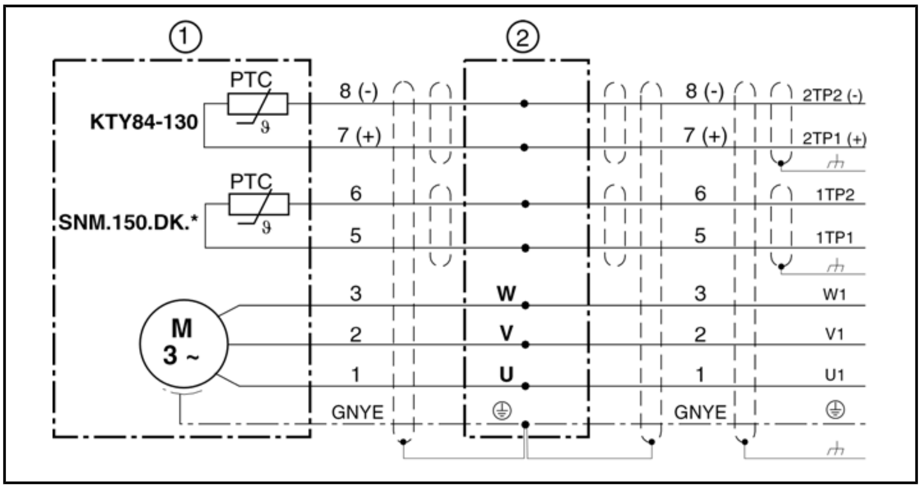
### Connection via Flange Socket and Coupling




① Primary part MLP...
② Flange socket INS0486
③ Coupling INS0481

*Fig.8-4: Connection example with flange socket and coupling*

**Connection via Terminal Box**




① Primary part MLP...
② Terminal box

*Fig.8-5: Connection example with terminal box*

## Passing types and cable cross-sections

**Parallel Motor Connection**

When connecting a motor parallel on a drive controller, the following possibilities exist to assembly the connection cable.

- Passing a collective cable with a higher cross-section (fig. 8-8 "Parallel arrangement, collective connection cable " on page 90)
- Passing of two separate parallel cables (fig. 8-7 "Parallel arrangement, separate connection cable" on page 90)

The latter possibility gives maybe the advance of lower bending radius. The entire cross-section of the parallel passed cables must correspond to the higher cross-section for parallel motor connection.

**Power connection at separate arrangement**

Electrical Connection

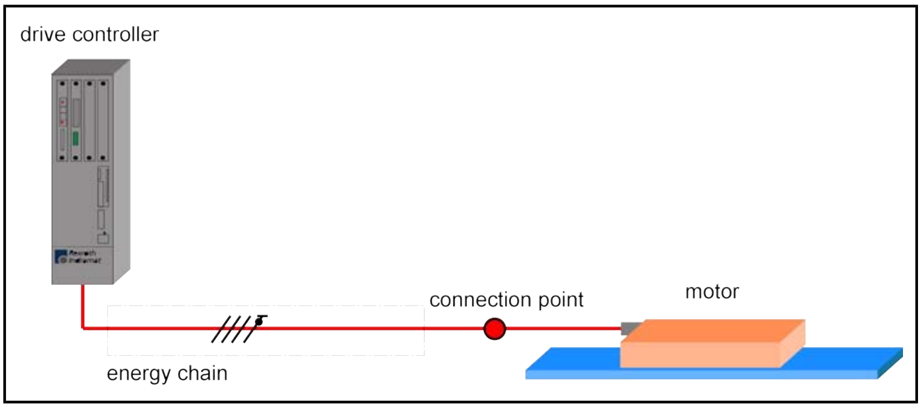



*Fig.8-6: Power connection at separate arrangement*

**Power connection at parallel arrangement, separate connection cable**

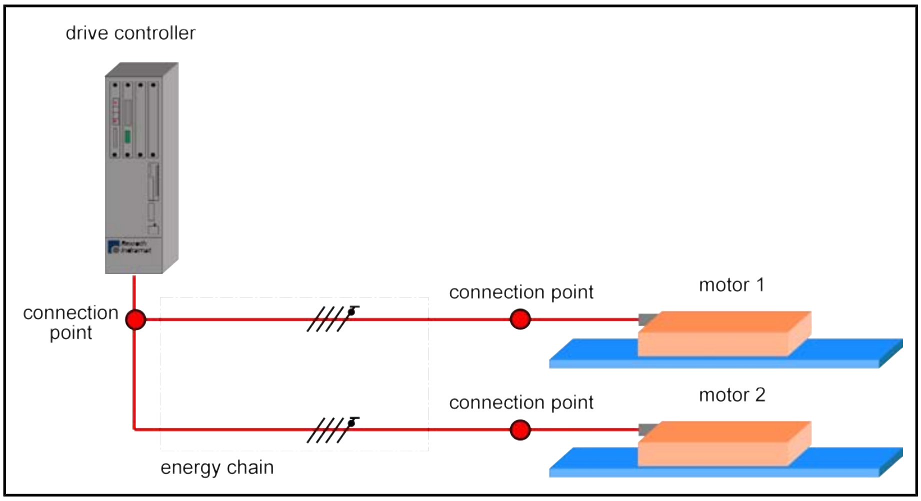



*Fig.8-7: Parallel arrangement, separate connection cable*

**Power connection at parallel arrangement, collective connection cable with higher cross-section**

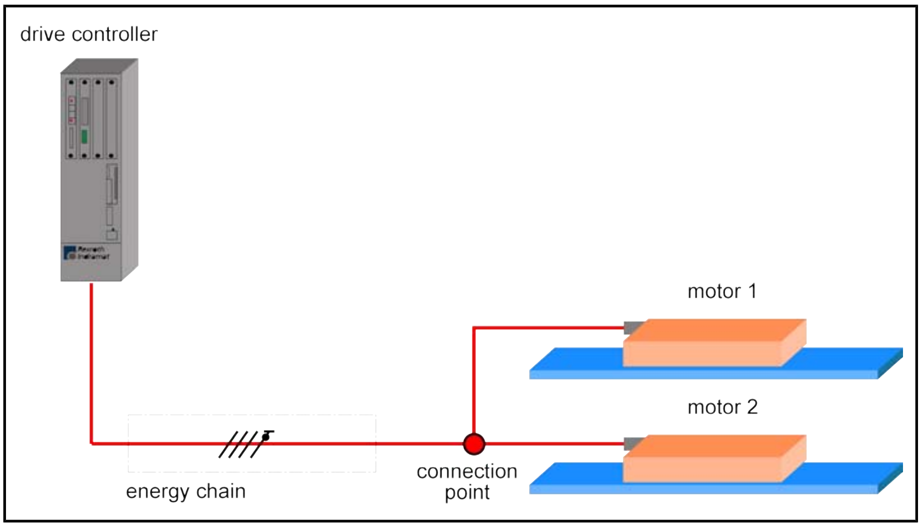



*Fig.8-8: Parallel arrangement, collective connection cable*

**Connecting Cables**

The selection of the exact cable cross-section depend on the passing type and is to be made according to the table below.

| Primary Part MLP... | Motor Phase Current in A (Effective value) | Connection Cable at Single or Parallel Arrangement with separate Power Cables | Connection Cable at Parallel Arrangement with collective Power Cable |
|---|---|---|---|
| 040A-0300 | 4,2 | 1.0 mm² (INK653) | 1.0 mm² (INK653) |
| 040B-0150 | 4,2 | | |
| 040B-0250 | 5,3 | | |
| 040B-0350 | 6 | | |
| 070A-0150 | 5,5 | | |
| 070A-0220 | 6,3 | | |
| 070A-0300 | 10,5 | | 2.5 mm² (INK602) |
| 070B-0100 | 5,5 | | 1.0 mm² (INK653) |
| 070B-0120 | 5,8 | | |
| 070B-0150 | 6,2 | | |
| 070B-0250 | 10 | | 2.5 mm² (INK602) |
| 070B-0300 | 12 | | 4 mm² (INK603) |
| 070C-0120 | 8,9 | | 2.5 mm² (INK602) |
| 070C-0150 | 11,7 | | |
| 070C-0240 | 13 | | 4 mm² (INK603) |
| 070C-0300 | 19 | 2.5 mm² (INK602) | 6 mm² (INK604) |
| 100A-0090 | 6,6 | 1.0 mm² (INK653) | 1.5 mm² (INK650) |
| 100A-0120 | 8 | | 2.5 mm² (INK602) |
| 100A-0150 | 10 | | |
| 100A-0190 | 12 | | 4 mm² (INK603) |
| 100B-0120 | 12 | | |
| 100B-0250 | 22 | 2.5 mm² (INK602) | 10 mm² (INK605) |
| 100C-0090 | 13 | 1.0 mm² (INK653) | 4 mm² (INK603) |
| 100C-0120 | 15 | 1.5 mm² (INK650) | 6 mm² (INK604) |
| 100C-0190 | 23 | 4 mm² (INK603) | 10 mm² (INK605) |
| 140A-0120 | 12 | 1.0 mm² (INK653) | 4 mm² (INK603) |
| 140B-0090 | 15 | 1.5 mm² (INK650) | 6 mm² (INK604) |
| 140B-0120 | 18 | 2.5 mm² (INK602) | |
| 140C-0050 | 13 | 1.0 mm² (INK653) | 4 mm² (INK603) |
| 140C-0120 | 21 | 2.5 mm² (INK602) | 10 mm² (INK605) |
| 140C-0170 | 29 | 4 mm² (INK603) | 16 mm² (INK606) |
| 140C-0350 | 53 | 10 mm² (INK605) | ---- |
| 200A-0090 | 13 | 1.0 mm² (INK653) | 4 mm² (INK603) |
| 200A-0120 | 16 | 2.5 mm² (INK602) | 6 mm² (INK604) |
| 200B-0040 | 13 | 1.0 mm² (INK653) | 4 mm² (INK603) |

| Primary Part MLP... | Motor Phase Current in A (Effective value) | Connection Cable at Single or Parallel Arrangement with separate Power Cables | Connection Cable at Parallel Arrangement with collective Power Cable |
|---|---|---|---|
| 200B-0120 | 22 | 2.5 mm² (INK602) | 10 mm² (INK605) |
| 200C-0090 | 23,3 | 4 mm² (INK603) | |
| 200C-0120 | 30 | 6 mm² (INK604) | 16 mm² (INK606) |
| 200C-0170 | 46 | 10 mm² (INK605) | 25 mm² (INK607) |
| 200D-0060 | 28 | 4 mm² (INK603) | 10 mm² (INK605) |
| 200D-0100 | 46 | 10 mm² (INK605) | 25 mm² (INK607) |
| 200D-0120 | 53 | | ----- |
| 300A-0090 | 19 | 2.5 mm² (INK602) | 6 mm² (INK604) |
| 300A-0120 | 23 | 4 mm² (INK603) | 10 mm² (INK605) |
| 300B-0070 | 28 | | 16 mm² (INK606) |
| 300B-0120 | 35 | 6 mm² (INK604) | |
| 300C-0060 | 29 | 4 mm² (INK603) | |
| 300C-0090 | 37 | 6 mm² (INK604) | 25 mm² (INK607) |

*Fig.8-9: Necessary cross-section of the power wires depend on the motor type, arrangement and connection type*

For additional description about power cables on primary parts and additional power cables refer to documentation ”Connection Cable” MNR. R911282688.

## 8.1.3 Connection Designation on the Rexroth Drive Control Device

The following overview shows the connection and clamp designations for power connection and the motor temperature monitoring.

You will find further information about motor temperature overview in chapter 9.7 "Motor Temperature Monitoring " on page 132.

| Rexroth Drive Controller | Terminal Block Designation Power Connection | Clamp Designation Power Connection | Terminal Block Designation Motor Temperature Monitoring | Clamp Designation Motor Temperature Monitoring |
|---|---|---|---|---|
| (IndraDrive) HMS0x.x HMD0x.x | X5 | A1, A2, A3 | X6 | MotTemp+ MotTemp- |
| (DIAX04) HDS0x.x | | | | TM+ TM- |
| (ECODRIVE) DKCxx.x | | | | TM+ TM- |

*Fig.8-10: Terminal designation on Rexroth drive controllers*

**Separate arrangement**

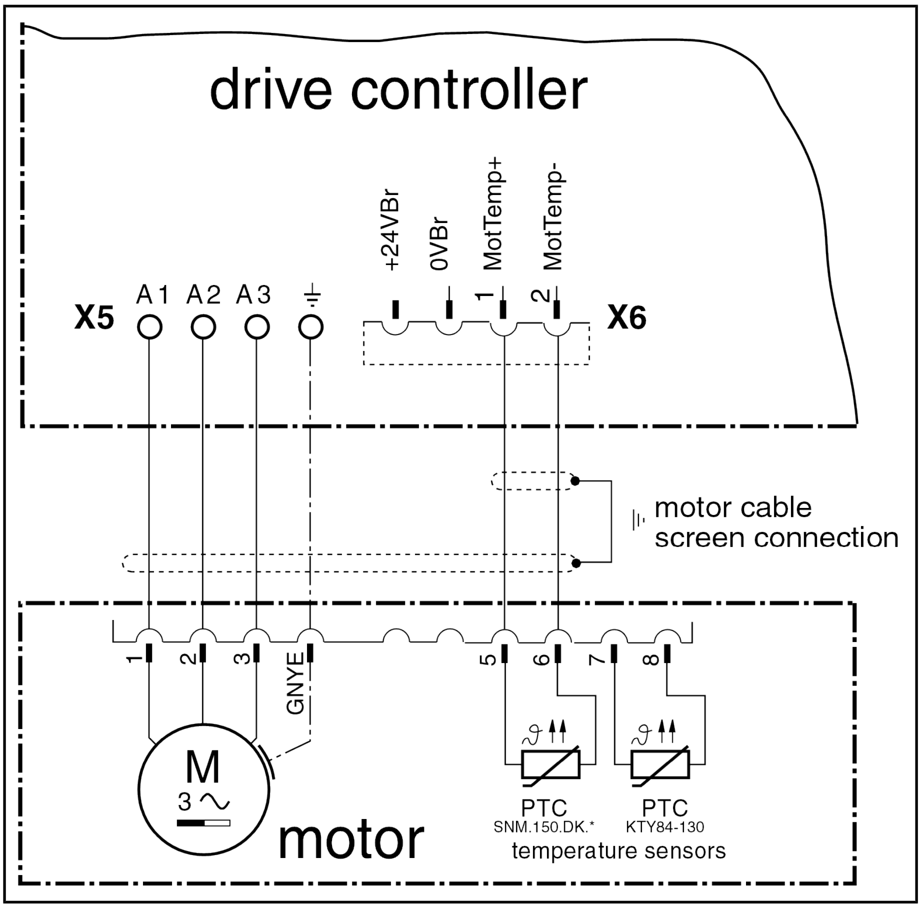



*Fig.8-11: Connection on the drive-controller – separate arrangement primary part*

**Parallel Arrangement**

Electrical Connection

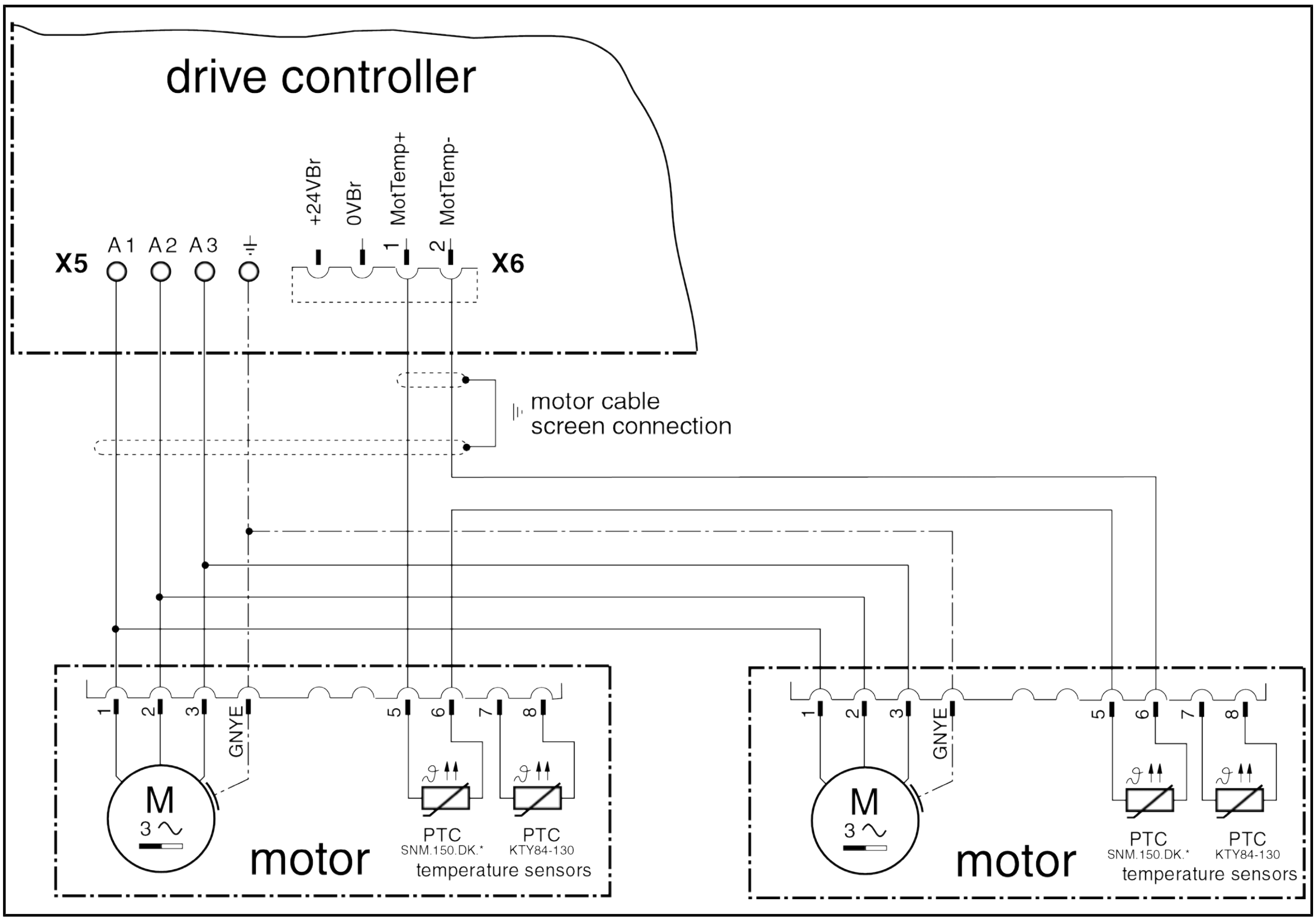



*Fig.8-12: Connection on the drive-controller – parallel arrangement primary part*

**Connection Power Cable for Primary Part at Parallel Arrangement**

The connection of the power wires of the connection cable on the drive controller at parallel arrangement of the primary parts with outgoing cable in the cross-direction depend on the direction of the outgoing cable.

| | | | |
|---|---|---|---|
| **Connection at arrangement acc. to fig. 9-16 "Arrangement of the primary parts behind each other and cable entry in the same direction" on page 107**<br>**(cable output in the same direction)** | | | |
| **Drive-controller X5** | A1 | A2 | A3 |
| Primary part 1 | A1 | A2 | A3 |
| Primary part 2 | A1 | A2 | A3 |
| **Connection at arrangement acc. to fig. 9-20 "Option 1: Arrangement of primary parts behind each other with cable entries in opposite directions" on page 108 and fig. 9-23 "Option 2: Arrangement of primary parts behind each other with cable entries in opposite directions" on page 109**<br>**(cable output in the opposite direction)** | | | |
| **Drive-controller X5** | A1 | A2 | A3 |

| Connection at arrangement acc. to fig. 9-16 "Arrangement of the primary parts behind each other and cable entry in the same direction" on page 107 (cable output in the same direction) | | | |
|---|---|---|---|
| Primary part 1 | A1 | A2 | A3 |
| Primary part 2 | A1 | A3 | A2 |

*Fig.8-13: Connection of the power wires at parallel arrangement of primary parts on a drive-controller*

## 8.2 Connection of Length Measurement System

The connection of the length measurement system is made via a ready-made cable.

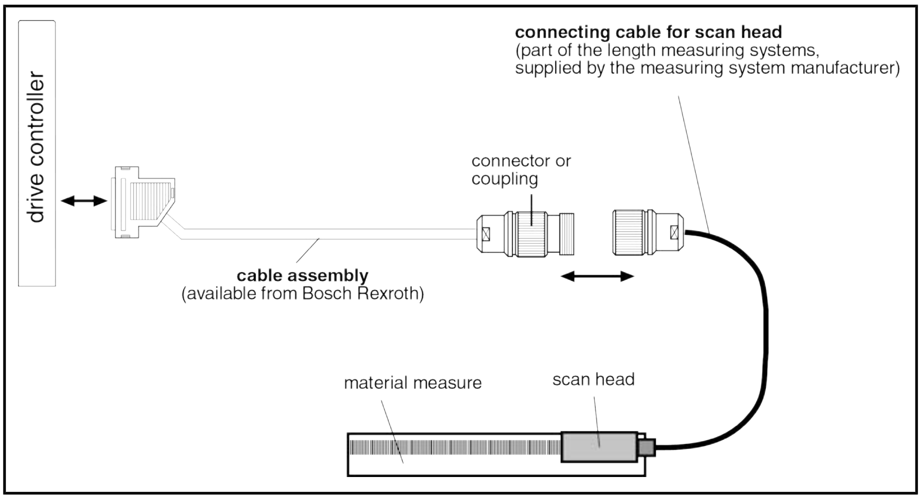



*Fig.8-14: Connection example length measurement system*

The following table shows an overview of the ready-made cable to the connection of the length measurement system.

| Measuring system type | Absolute, ENDAT | Incremental |
|---|---|---|
| Output variable | Stress | Stress |
| Signal flow line | Sinus | Sinus |
| Signal amplitude | 1VSS | 1VSS |
| Position interface | DAG | DLF |
| Depending on the connection mode of the length measuring system (flange socket or coupling), Rexroth offers two different ready-made connection cables to connect drive controller and measuring system: | | |

| Measuring system type | Absolute, ENDAT | Incremental |
|---|---|---|
| DIAX04 <--> Flange socket<br>DKCxx.3 <--> Flange socket<br>IndraDrive <--> Flange socket | IKS 4142<br>IKS 4001<br>IKS 4038 | IKS 4384<br>IKS 4002<br>IKS 4041 |
| DIAX04 <--> Coupling<br>DKCxx.3 <--> Coupling<br>IndraDrive <--> Coupling | ---<br>---<br>--- | IKS 4383<br>IKS 4389<br>IKS 4040 |

*Fig.8-15: Connection components length measurement system*

For additional description see documentation ”Connection Cable” selection data, MNR R911282688.

# 9 Application and Construction Instructions

## 9.1 Functional Principle

The following figure shows the principal design of IndraDyn L motors.

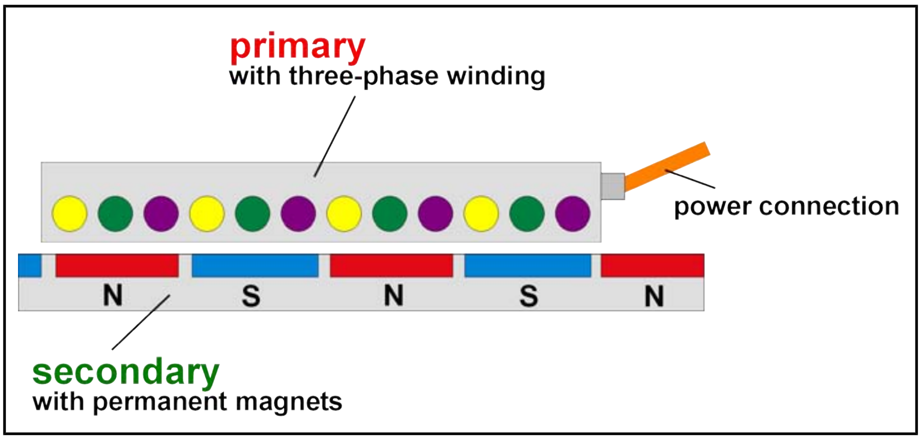



*Fig.9-1: General construction of an IndraDyn L motor*

The force generation of the IndraDyn L motor, a synchronous-linear motor, is the same as the torque generation at rotative synchronous motors. The primary part (active part) has a three-phase winding; the secondary part (passive part) has permanent magnets.

Both, the primary part and the secondary part can be moved.

Realization of any traverse path length can be done by stringing together several secondary part segments.

**Axis Construction**

The IndraDyn L motor is a kit motor. The components primary and secondary part(s) are delivered separately and completed by the user by linear guide and the linear measuring system.

The construction of an axis fitted with an IndraDyn L motor normally consists of

- Primary part with three-phase winding,
- One or more secondary parts with permanent magnets,
- Linear scale
- Linear guide,
- Energy flow as well as
- Slide or machine construction

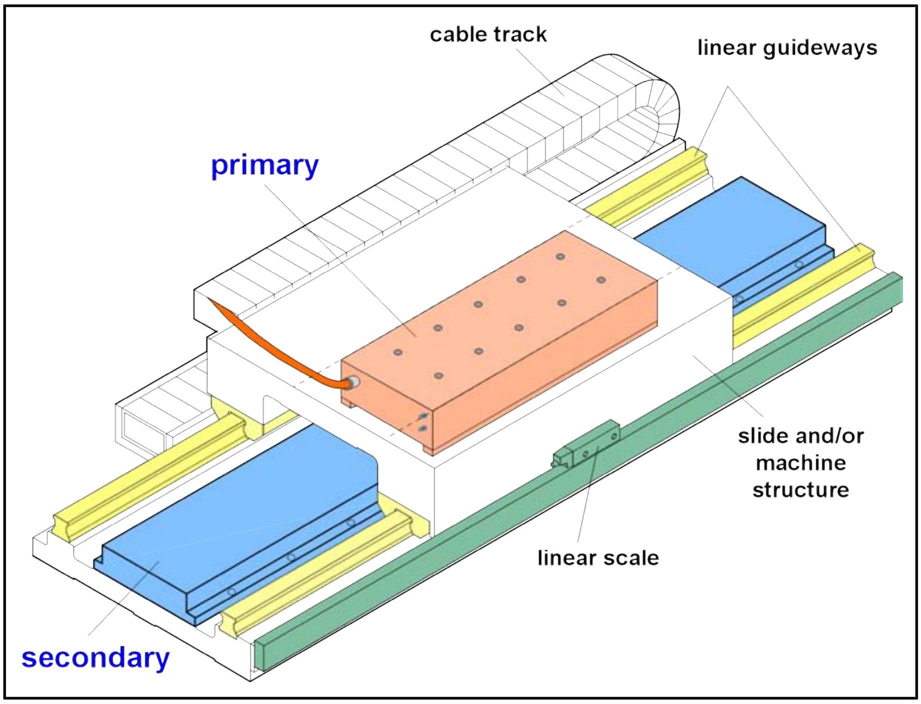



*Fig.9-2: General construction of an axis with an IndraDyn L*

For force multiplication can be two or more primary parts mechanically coupled, arranged parallel or in-line. For further information see chapter 9.4.2 "Several Motors per Axis" on page 104.

☞ Only the primary and the secondary part(s) belong to the scope of delivery of the motor.

☞ Linear guide and length scale as well as further additional components have to be made available by the user. For recommendations to tested additional components, refer to chapter 15.1 "Recommended Suppliers of Additional Components " on page 247.

# 9.2 Motor Design

## 9.2.1 General Information

IndraDyn L motors of Bosch Rexroth are tested drive components. They have the following characters:

- Modular system with different motor sizes and lengths for feed forces up to 21.500 N per motor and speeds over 600 m/min
- Different winding constructions at any motor size for optimum adjustment to different speed demands.
- All motor components are completely encapsulated, i.e. crack initiation within casting compounds, damage or corrosion of magnets a.s.o. are excluded.
- Different designs regarding cooling and encapsulation of the primary part (see below: standard and thermo encapsulation)
- Protection class IP65 (all motor components)
- High operation safety for DC bus voltage up to 750V.
- No mechanical deterioration

- Protection of the motor winding against thermal overstress by integrated temperature sensors
- Flexible, shielded and strain-bearing power lead wire

**Design of cooling and encapsulation**

To make the optimum motor for the different uses, regarding technical demands and costs available, are primary parts in different designs in cooling and encapsulation available.

- **Standard encapsulation:** stainless steel encapsulation with a liquid cooling integrated into the back of the motor to dissipate the lost heat.
- **Thermal encapsulation:** stainless steel encapsulation with an additional liquid cooling on the back of the motor and heat conductive plates for optimum thermal decoupling to the machine construction.

## 9.2.2 Primary Part Standard Encapsulation

At use with less thermal demands on the machine accuracy, primary parts in standard encapsulation present an economy solution. Primary parts with standard encapsulation are mainly used in the general automation sector. There, the electrical motor components are protected by a stainless steel encapsulation. The cooling system of this motor design is integrated into the motor and can only be used to discharge lost heat or keeping the specified continuous feedrate. It offers no additional thermal decoupling on the motor side to the machine.

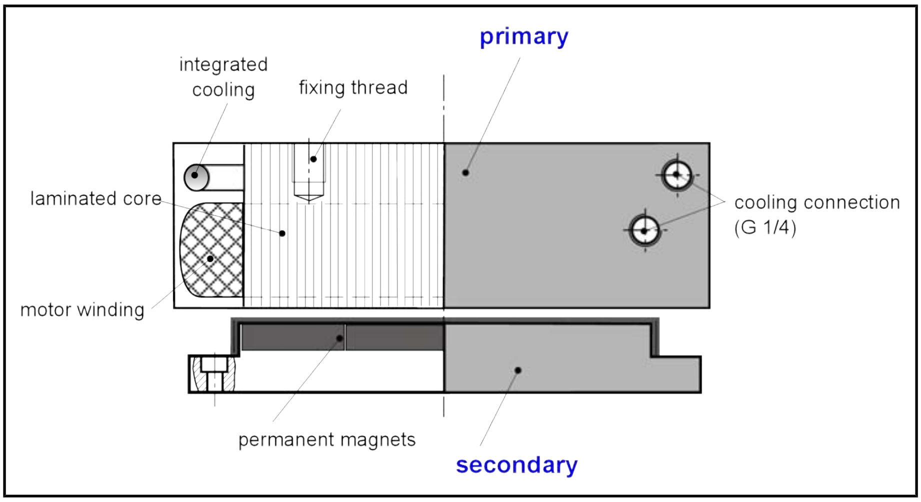



*Fig.9-3: Primary part with standard encapsulation*

For further notes regarding liquid cooling refer to chapter 9.6 "Motor Cooling System" on page 116.

**Main application area**

The main application areas of this design of the primary part can be found in the sectors:

- General automation
- Handling

## 9.2.3 Primary Part Thermo Encapsulation

Primary parts in thermal encapsulation reach an high constant temperature on the mounting surface due to an additional – into the encapsulation integrated liquid coolant for thermal encapsulation to the machine construction. At design ”Thermal encapsulation”, a maximum temperature rise on the screw-on surface in opposite to the coolant inlet temperature of 2 K can be reached.

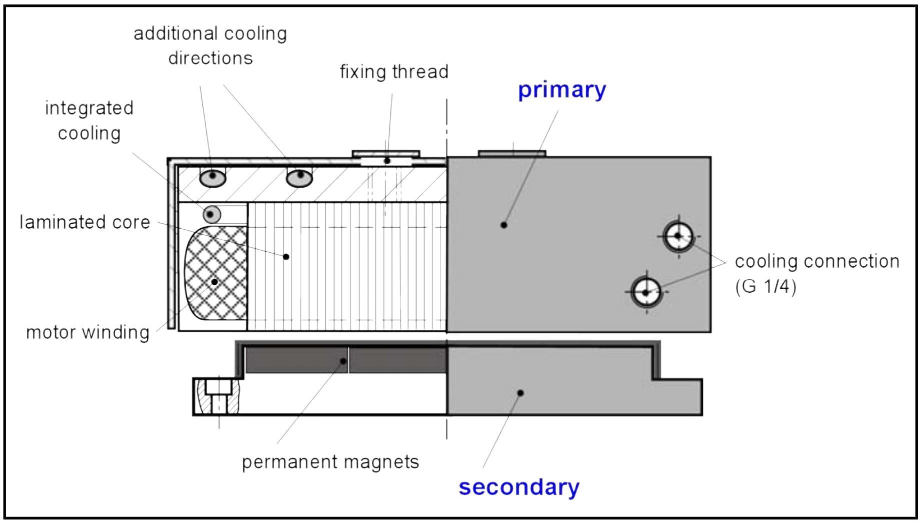



*Fig.9-4: Primary part with thermo encapsulation*

The primary part is not completely connected with the mounting surface on the machine side, but only lays on increased bearing points. This offers the following advantages:

- Additional thermal encapsulation and therewith further minimization of the possible heat-flow into the machine
- Processing of the screw-on surface on the machine side makes it easier to keep the necessary mounting tolerances.

☞ For further notes regarding liquid cooling refer to chapter 9.6 "Motor Cooling System" on page 116.

**Main Application Area**

Main application areas of this primary part design are, e.g.

- Machine tools
- Precision applications

## 9.2.4 Design Secondary Part

The secondary part or a secondary part segment consists of a steel base plate with fitted permanent magnets. The fastening holes are located on the outer edge along the secondary part.

To ensure the utmost operation reliability, the permanent magnets of the secondary part are always protected against corrosion, action of outer influences (e.g. coolants and oil) and against mechanical damage, due to an integrated rustless cover plate.

It is possible to use a scraper direct on the secondary part (see chapter 9.20 "Wipers" on page 147).

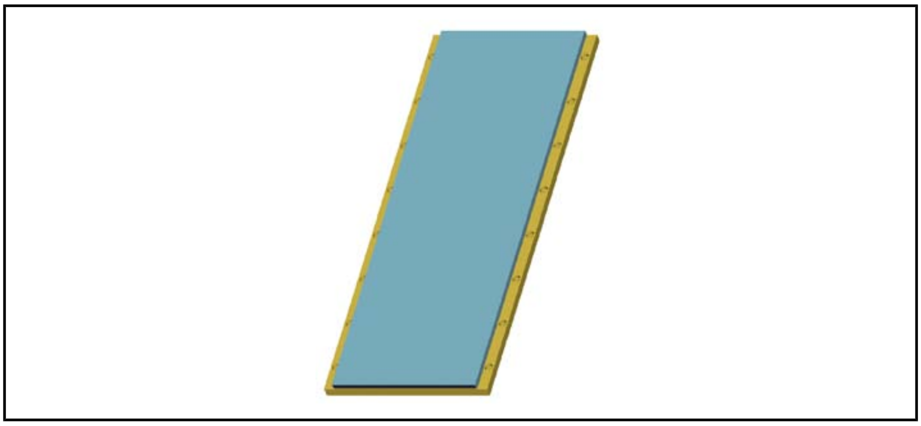


*Fig.9-5: Secondary part MLS*

☞ The design of the secondary part is independent from the design of the primary part.

**Available Lengths Secondary Parts**

Secondary parts or secondary part segments are available in the following lengths (see also chapter 6 "Type Code IndraDyn L" on page 69).

- 150 mm
- 450 mm
- 600 mm

**Required Length of the Secondary Parts**

The required length L of the secondary part can be defined as follows:

$$L_{\text{Secondary part}} \geq L_{\text{Traversepath}} + L_{\text{Primarypart}}$$

*Fig.9-6: Defining the required length of the secondary part*

## 9.2.5 Frame Sizes

For adjusting on different feed force requirements, Bosch Rexroth offers IndraDyn L motors in a modular system with different sizes and lengths.

The active breadth of primary and secondary parts at linear motors serve to define the size. A linear motor with e.g. size 100 has a laminated core and magnet breadth of 100 mm. The IndraDyn L modular system contains the following motor sizes:

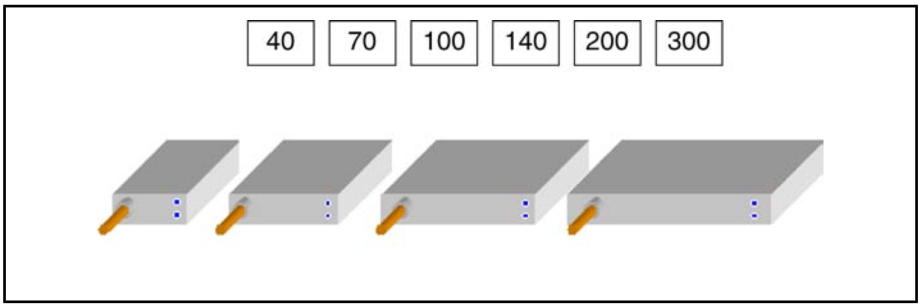



*Fig.9-7: Sizes of IndraDyn L synchronous linear motors*

**Sizes**

Every primary part is graduated in different motor lengths. The designation of the length of the primary part is done by the letters A, B, C, D.

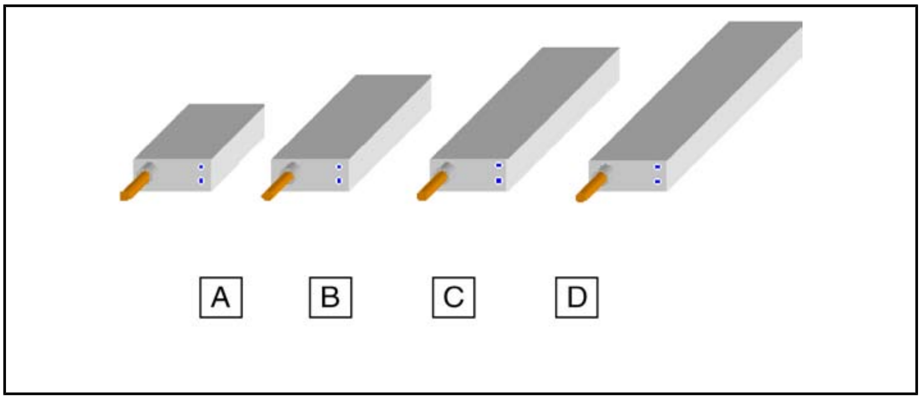



*Fig.9-8: Different lengths of primary parts*

For detailed information regarding frame sizes and lengths refer to chapter 5 "Dimensions, Installation Dimensions and -Tolerances" on page 49.

# 9.3 Requirements on the Machine Design

## 9.3.1 General Information

Derived from design and properties of linear direct drives, the machine design must meet various requirements. For example, the moved masses should be minimized whilst the rigidity is kept at a high level.

## 9.3.2 Mass Reduction

To ensure a high acceleration capability, the mass of the moved machine elements must be reduced to a minimum. This can be done by using materials of a low specific weight (e.g. aluminum or compound materials) and by design measures (e.g. skeleton structures).

If there are no requirements for extreme acceleration, masses up to several tons can be moved without any problems. There is no control-engineering correlation between the moved slide mass and the motor´s mass, as this is the case with rotary drives.

Precondition therefore is, a very rigid coupling of the motor to the weight.

## 9.3.3 Mass Rigidity

In conjunction with the mass and the resulting resonant frequency, the rigidity of the individual mechanical components within a machine chiefly determines the quality a machine can reach. The rigidity of a motion axis is determined by the overall mechanical structure. The goal of the construction must be to obtain an axis structure that is as compact as possible.

**Natural Frequency**

The increased loop bandwidth of linear drives required higher mechanical natural frequencies of the machine structure in order to avoid the excitation of vibrations.

To ensure a sufficient control quality, the lowest natural frequency that occurs inside the axis should not be less than approximately 200 Hz. The natural frequencies of axes with masses that are not constantly moving (e.g. due to workpieces that must be machined differently) change, so that the natural frequency is reduced with $f \approx \sqrt{1/m}$ as the mass increases.

**Mechanically Linked Axes**

The elasticity´s of the axes (both, the mechanical and the control-engineering component) add up. This must be taken into account with respect to the rigidity of cinematically coupled axes.

If several axes must cinematically be coupled in order to produce path motions (e.g. cross-table or gantry structure), the mutual effects of the individual axes on each other should be minimized. Thus, cinematic chains should be avoided in machines with several axes. Axis configurations with long projections that change during operation are particularly critical.

**Reactive Forces**

Initiated by acceleration, deceleration or process forces of the moved axis, reactive forces can deform the stationary machine base or cause it to vibrate.

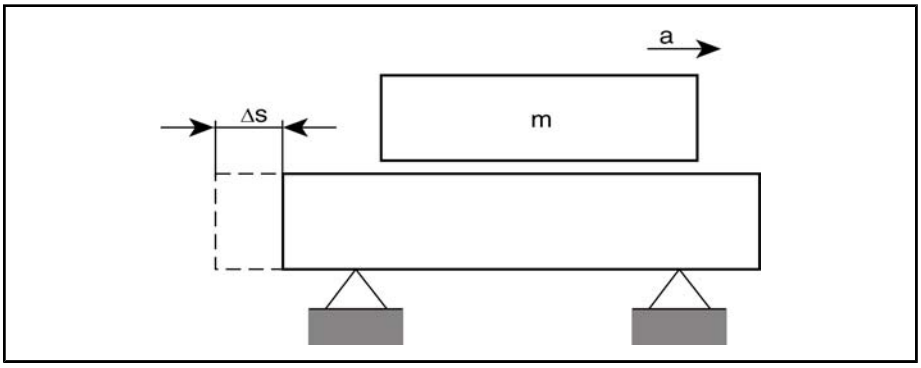



*Fig.9-9: Deformation of the machine base caused by the reactive force during the acceleration process*

$$\Delta s = \frac{m \cdot a}{c} = \frac{500\ \text{kg} \cdot 10\ \text{m/s}^2}{1000\ \text{N}/\mu\text{m}} = 5\ \mu\text{m}$$

| | |
|---|---|
| Δs | Deformation of displacement of the machine base in µm |
| m | Mass in kg |
| a | Acceleration in $m/s^2$ |
| c | Rigidity of the machine base in N/µm |

*Fig.9-10: Typical calculation of the machine base deformation*

**Integrating the linear scale**

The rigidity of the length measuring system integration is particularly important. For explanations refer to chapter 9.15 "Length Measuring System " on page 139.

## 9.3.4 Protection of the Motor Installation Space

To avoid contamination of the motor during operation (due to any kind of residues, swarfs, respirable dust, grease of the guides, etc.) within the air gap between the primary and secondary part, you should especially pay attention to the protection of the motor installation space.

Heed appropriate protection measures when designing the machine construction, for example:

- self-made covers
- bellows covers

If dirt penetrates between the motor components due to insufficient protection measures, this can lead during operaton to ...

- an increased heat introduction due to friction between the motor components. Hereby, temperatures can occur that lead to motor breakdown.
- Grinding traces and/or scratch-formation on the motor components which can lead to motor breakdown due to high mechanical force effect.

Please observe that dirt can also be brought into via coolant residues, preasure air and other machine parts (e.g. grease of the guides). This must be prevented.

Make sure by regularly maintenance of the safety measures that their function is still kept and the motor components could not be damaged.

# 9.4 Arrangement of Motor Components

## 9.4.1 Single Arrangement

The single arrangement of the primary part is the most common arrangement.

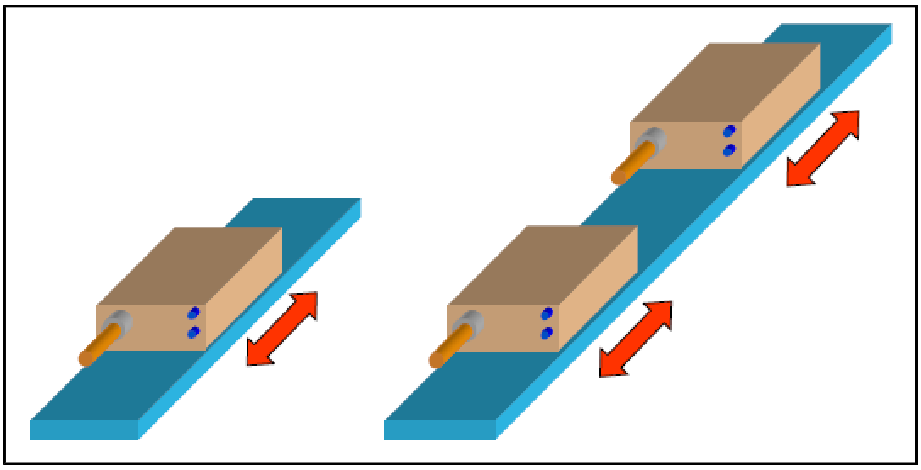


*Fig.9-11: Single arrangement of primary parts*

The independent operation of two or more primary parts on one secondary part is possible, too. In such an arrangement, the length measuring system can also be equipped with two or more scanning heads.

☞ Due to the higher sealing lip friction, the quantity of scanning heads in encapsulated linear scales is usually limited to two. Please contact the scale manufacturer for details.

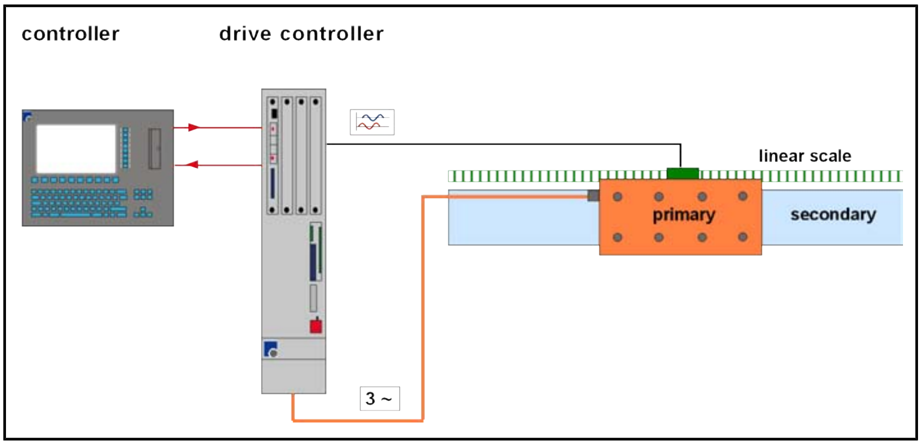



*Fig.9-12: Controlling a linear motor with single arrangement of the motor components*

## 9.4.2 Several Motors per Axis

### General Information

The arrangement of several motors per axis provides the following benefits:

- Multiplied feed forces

- With corresponding arrangement, compensation of the attractive forces ”outwards”

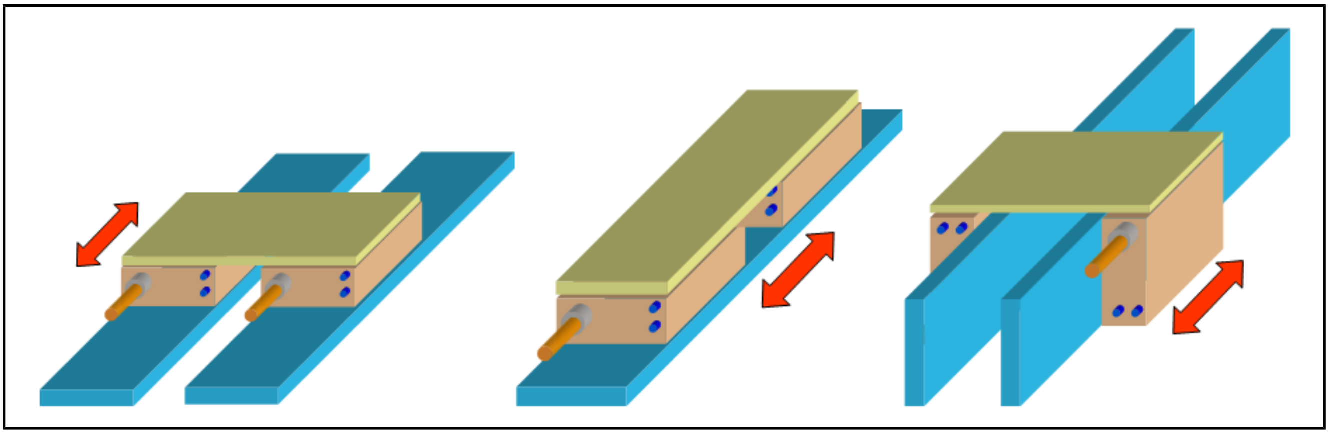


*Fig.9-13: Arrangement of several motors per axis*

Depending on the application, the motors can be controlled in two different ways:

- Two motors at one drive controller and one linear scale (parallel arrangement)
- Two motors at two drive controllers and two linear scales (Gantry arrangement)

## Parallel Arrangement

The arrangement of two or more primary parts on one drive controller in conjunction with a linear scale is known as parallel arrangement. Parallel arrangement is possible if the coupling between the motors can be very rigid.

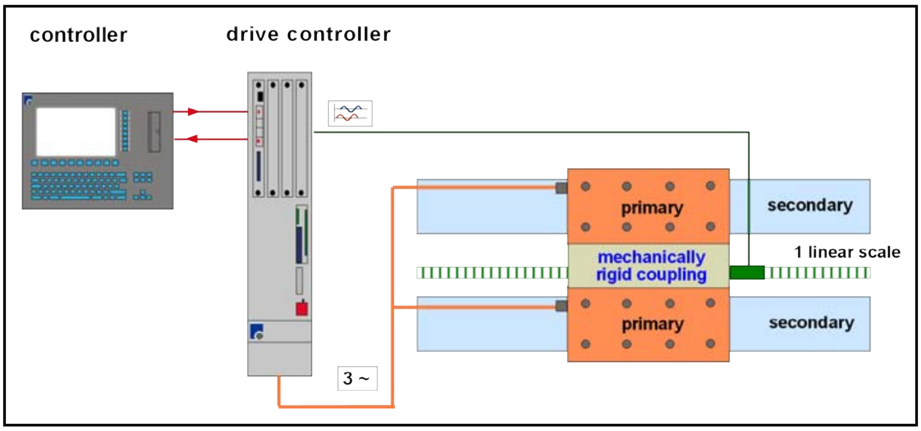



*Fig.9-14: Parallel arrangement of two primary parts on one drive controller in conjunction with a length measuring system*

To ensure successful operation, the axis must fulfill the following requirements in parallel arrangement:

- Identical primary and secondary parts
- Very rigid coupling of the motors within the axis
- Position offset between the primary parts <1 mm in feed direction
- Position offset between the secondary parts <1 mm in feed direction
- Same pole sequence of the secondary parts
- If possible, load stationary and arranged symmetrically with respect to the motors

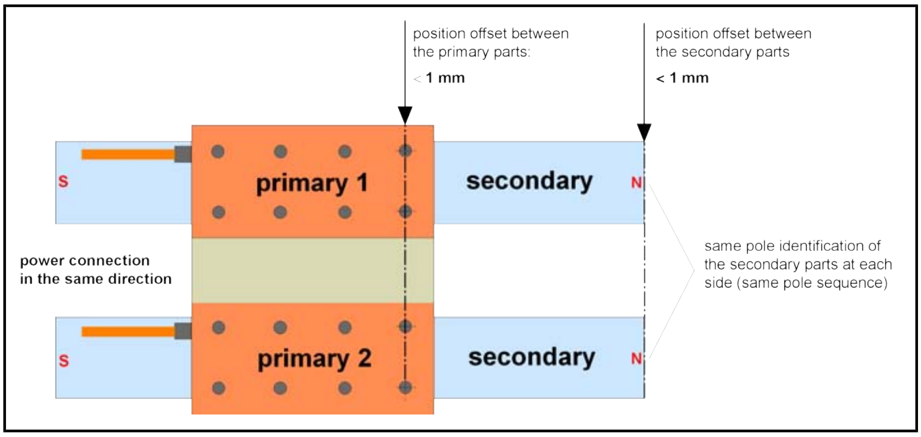



*Fig.9-15: Alignment of motor components in parallel arrangement*

The mounting holes of the primary parts are used for defining the correct position of the paralleled motors. Use always the same hole in the grid of both primary parts (see fig. 9-15 "Alignment of motor components in parallel arrangement" on page 106). An offset of the hole grid between the primary parts is only permitted in the structures shown in fig. 9-17 "Determining the grid distance between the primary parts with cable entries in the same direction" on page 107 or fig. 9-18 "Distance xpmin to be kept between the two primary parts with cable entries in the same direction" on page 107.

The face ends of the primary parts may alternatively be used if the mounting holes cannot be employed as position reference. The motor parts have the corresponding tolerances.

## Parallel arrangement: Double Comb Arrangement

In a parallel arrangment – also within a Gantry arrangement – the primary parts in feed direction can be mechanically coupled and arranged in the form of a ”double comb arrangement” (see right-hand side). In addition to the force multiplication, the attractive forces between primary and secondary part are compensated towards the outside. With the corresponding arrangement, the linear guides are not stressed additionally, and may even be sized smaller.

Double comb arrangement (acc. to fig. 9-13 "Arrangement of several motors per axis" on page 105 right-hand side) does **not** require a minimum distance to be kept between the two secondary part mounting surfaces.

## Parallel arrangement: Arrangement of primary parts in succession

In a parallel arrangement – also within a Gantry arrangement – the primary parts in feed direction can be mechanically coupled and arranged in succession (see fig. 9-13 "Arrangement of several motors per axis" on page 105, center).

To ensure successful operation, the primary parts must be arranged in a specific grid. The determination of the grid sizes that must be adhered, depends on the direction of the cable entry and the permissible bending radius of the power cable.

**Cable entry in the same direction**

If the primary parts are arranged behind each other with the cable entries in the same direction acc. to fig. 9-16 "Arrangement of the primary parts behind each other and cable entry in the same direction" on page 107, an integer multiple of twice the electrical pole pitch must be adhered to:

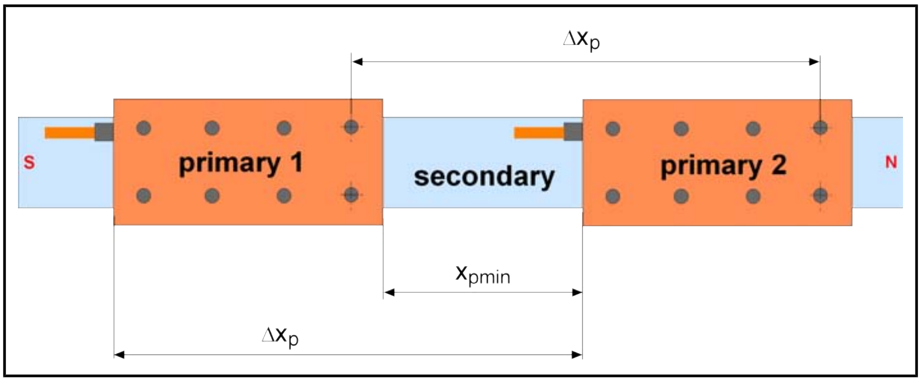



*Fig.9-16: Arrangement of the primary parts behind each other and cable entry in the same direction*

☞ When you determine the correct primary part distance with cable entries in the same direction acc. to fig. 9-16 "Arrangement of the primary parts behind each other and cable entry in the same direction" on page 107, you must always use the same reference point for both primary parts (e.g. the same fastening hole).

$$\Delta x_p = n \cdot 2 \cdot \tau_p$$

| | |
|---|---|
| $\Delta x_P$ | Required grid spacing between the primary parts in mm |
| $\tau_P$ | Electrical pole pitch in IndraDyn L motors in mm (all sizes 37.5 mm) |
| n | Integer factor (depends on mounting distance) |

*Fig.9-17: Determining the grid distance between the primary parts with cable entries in the same direction*

**Minimum Distances between Primary Parts**

According to fig. 9-16 "Arrangement of the primary parts behind each other and cable entry in the same direction" on page 107 and fig. 9-17 "Determining the grid distance between the primary parts with cable entries in the same direction" on page 107 result size-related minimum distances between the primary parts at a motor arrangement with cable output into the same direction:

| Motor version | $X_{pmin}$ in mm |
|---|---|
| **Standard encapsulation**frame sizes (all) | $15\ mm + n \cdot 2 \cdot \tau_p$ |
| **Thermal encapsulation** frame sizes (all) | $65\ mm + n \cdot 2 \cdot \tau_p$ |

| | |
|---|---|
| n | The integer factor n must be chosen in that way, so that the following conditions can be kept. |
| $\tau_P$ | Electrical pole pitch in IndraDyn L motors in mm (all sizes 37.5 mm) |

*Fig.9-18: Distance xpmin to be kept between the two primary parts with cable entries in the same direction*

**Requirement**

$$X_{pmin} > \text{permissible bending radius motor cable}$$

*Fig.9-19: Distance xpmin to be kept between the two primary parts with cable entries in the same direction*

**Cable entry in opposite direction**

**Option 1:**

If the primary parts are arranged behind each other and with cable entries in opposite directions to fig. 9-20 "Option 1: Arrangement of primary parts behind each other with cable entries in opposite directions" on page 108, a defined distance must be kept between the primary parts according to fig. 9-21 "Determining the grid distance between primary parts with cable entries in opposite directions" on page 108 and fig. 9-22 "Distance xpmin to be kept between the two primary parts with cable entries in opposite direction" on page 108.

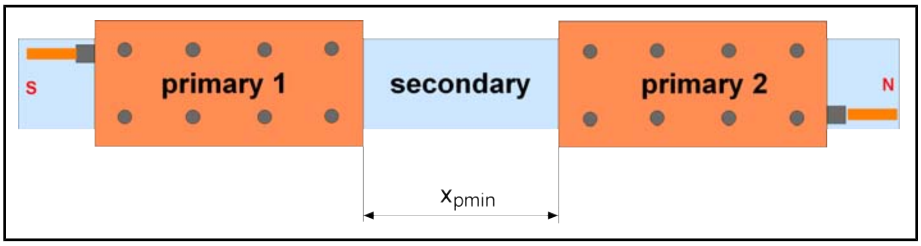



*Fig.9-20: Option 1: Arrangement of primary parts behind each other with cable entries in opposite directions*

When you determine the correct primary part distance with cable entries in opposite directions according to fig. 9-20 "Option 1: Arrangement of primary parts behind each other with cable entries in opposite directions" on page 108 and fig. 9-23 "Option 2: Arrangement of primary parts behind each other with cable entries in opposite directions" on page 109, you can only use the distance between the primary part end faces $x_p$ as reference point.

$$x_P = n \cdot 2 \cdot \tau_p + x_{pmin}$$

| | |
|---|---|
| $x_P$ | Required grid spacing between the primary parts in mm |
| $\tau_P$ | Electrical pole pitch in IndraDyn L motors in mm (all sizes 37.5 mm) |
| n | Integer factor (depends on mounting distance) |

*Fig.9-21: Determining the grid distance between primary parts with cable entries in opposite directions*

**Minimum distance between the primary parts (option 1)**

For a motor arrangement with cable entries at opposite directions, the following size-related minimum distances between primary parts result from:

| Motor version | $X_{pmin}$ in mm |
|---|---|
| **Standard encapsulation**<br>Frame sizes (all) | 65 |
| **Thermal encapsulation**<br>Frame sizes (all) | 59 |

*Fig.9-22: Distance xpmin to be kept between the two primary parts with cable entries in opposite direction*

**Cable Entry in opposite Direction**

**Option 2:**

If the primary parts are arranged in a row and with cable entries in opposite directions to fig. 9-23 "Option 2: Arrangement of primary parts behind each other with cable entries in opposite directions" on page 109, a defined distance must be kept between the primary parts according to fig. 9-24 "Determining the grid distance between primary parts with cable entries in opposite directions" on page 109 and fig. 9-25 "Distance xpmin to be kept between the two primary parts with cable entries in opposite direction" on page 109.

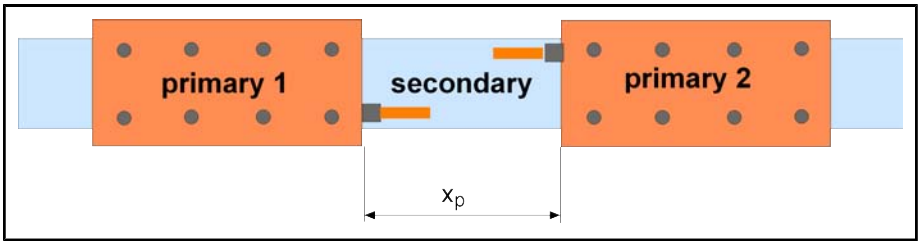



*Fig.9-23: Option 2: Arrangement of primary parts behind each other with cable entries in opposite directions*

☞ When you determine the correct primary part distance with cable entries in opposite directions according to fig. 9-20 "Option 1: Arrangement of primary parts behind each other with cable entries in opposite directions" on page 108 and fig. 9-23 "Option 2: Arrangement of primary parts behind each other with cable entries in opposite directions" on page 109, you can only use the distance between the primary part end faces $x_p$ as reference point.

$$x_P = n \cdot 2 \cdot \tau_p + x_{p\,min}$$

| | |
|---|---|
| $x_P$ | Required grid spacing between the primary parts in mm |
| $\tau_P$ | Electrical pole pitch in IndraDyn L motors in mm (all sizes 37.5 mm) |
| n | Integer factor (depends on mounting distance) |

*Fig.9-24: Determining the grid distance between primary parts with cable entries in opposite directions*

**Minimum Distance between the Primary Parts (Option 2)**

For a motor arrangement with cable entries at opposite directions, the following size-related minimum distances between primary parts result from:

| Motor version | $X_{pmin}$ in mm |
|---|---|
| **Standard encapsulation**<br>Frame sizes (all) | $40mm + n \cdot 2 \cdot \tau_p$ |
| **Thermal encapsulation**<br>Frame sizes (all) | $71mm + n \cdot 2 \cdot \tau_p$ |

| | |
|---|---|
| n | The integer factor n must be chosen in that way, so that the following conditions can be kept. |
| $\tau_P$ | Electrical pole pitch in IndraDyn L motors in mm (all sizes 37.5 mm) |

*Fig.9-25: Distance xpmin to be kept between the two primary parts with cable entries in opposite direction*

**Requirement**

$$x_{p\,min} > \text{permissible bending radius motor cable}$$

*Fig.9-26: Distance xpmin to be kept between the two primary parts with cable entries in opposite direction*

**Power Cable Connection**

The connection of the power wires of the connection cable on the drive controller at parallel arrangement of the primary parts with outgoing cable in the cross-direction depend on the direction of the outgoing cable.

| Connection at arrangement with cable output into the same direction (see fig. 9-16 "Arrangement of the primary parts behind each other and cable entry in the same direction" on page 107) | | | |
|---|---|---|---|
| Drive-controller X5 | 1 | 2 | 3 |
| Primary part 1 | 1 | 2 | 3 |
| Primary part 2 | 1 | 2 | 3 |
| **Connection at arrangement with cable output into the opposite direction** (see fig. 9-20 "Option 1: Arrangement of primary parts behind each other with cable entries in opposite directions" on page 108 and fig. 9-23 "Option 2: Arrangement of primary parts behind each other with cable entries in opposite directions" on page 109) | | | |
| Drive-controller X5 | 1 | **2** | **3** |
| Primary part 1 | 1 | 2 | 3 |
| Primary part 2 | 1 | **3** | **2** |

*Fig.9-27: Connection of the power wires at parallel arrangement of primary parts on a drive-controller*

☞ The primary part 1 according to fig. 9-20 "Option 1: Arrangement of primary parts behind each other with cable entries in opposite directions" on page 108 and fig. 9-23 "Option 2: Arrangement of primary parts behind each other with cable entries in opposite directions" on page 109is always the reference motor that is used for determining the sensor polarity and for commutation setting (refer also to chapter 14 "Commissioning, Operation and Maintenance" on page 227). Ensure that the secondary part is correctly aligned.

You will find further information about electrical connection in chapter 8 "Electrical Connection" on page 87.

## Gantry Arrangement

Operation with two linear scales and drive controllers (Gantry arrangement) should be planned if there are load conditions that are different with respect to place and time, and sufficient rigidity between the motors cannot be ensured. This is frequently the case with axis in a Gantry structure, for example.

☞ Parallel motors may also be used with a Gantry arrangement.

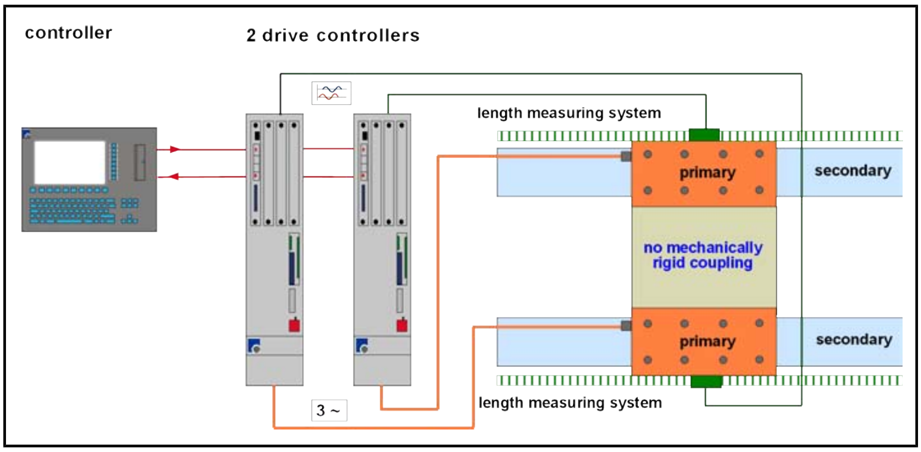



*Fig.9-28: Gantry arrangement*

With Gantry arrangements it must be remembered that the motors may be stressed unsymmetrically, although the position offset is minimized. As a consequence, this permanently existing bas load may lead to a generally higher stress than in a single arrangement. This must be taken into account when the drive is selected.

☞ The asymmetric capacity can be reduced to a minimum by exactly aligning the length measuring system and the primary and secondary parts to each other, and by a drive-internal axis error compensation.

### 9.4.3 Vertical Axis

WARNING

**Uncontrolled movements**

⇒ When linear motors are used in vertical axes, it must be taken into account that the motor is not self-locking when power is switched off. Sinking the axis can only be secured by an appropriate holding brake (see chapter 9.17 "Braking Systems and Holding Devices" on page 145).

Suitable holding devices must be used for preventing the axis from sinking after the power has been switched off. These holding devices can be actuated electrically, pneumatically or hydraulically.

☞
- Adequate holding devices are integrated in most of today´s weight compensation systems.
- On vertical axis, the use of an absolute measuring system is recommended. Alternatively, also an incremental measuring system, in connection with a Hall sensor box can be used (see chapter 7 "Accessories and Options" on page 85).

**Weight Compensation**

An additionally used weight compensation ensures that the motor is not exposed to an unnecessary thermal stress that is caused by the holding forces and the acceleration capability of the axis is independent of the motion direction. The weight compensation can be pneumatic or hydraulic.

Weight compensation with a counterweight is not suitable since the counterweight must also be accelerated.

## 9.5 Feed and Attractive Forces

### 9.5.1 Attractive Forces between Primary and Secondary Part

When it is installed, a synchronous linear motor has a permanently effective attractive force between primary and secondary part that results from its principle. With synchronous linear motors, this attractive force also exists when the motor is switched off.

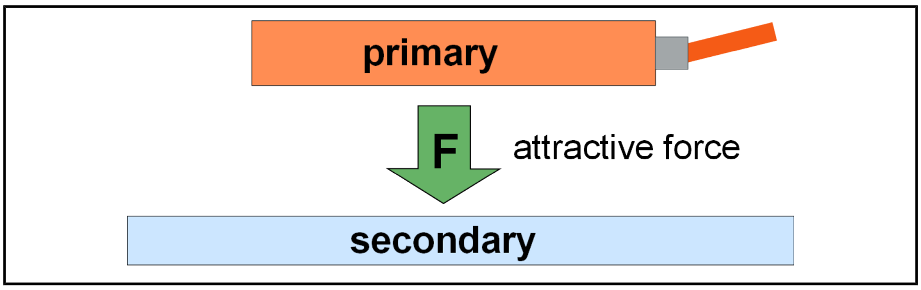



*Fig.9-29: Attractive force between primary and secondary part*

**Considering the Attractive Force in Motor Installation**

These attractive forced must always be taken into account in the mechanical design of the system.

With an unfavorable arrangement of the motors, the attractive forces can cause deformations (deflection) in the machine structure and unacceptable transverse stress on the linear guides. The following points should therefore be taken into account during the design integration of the motors:

- Arrange the linear guides as close to the motor as possible.
- To compensate the attractive forces, you can use the parallel arrangement shown at the right-hand side in fig. 9-13 "Arrangement of several motors per axis" on page 105.

**CAUTION**

**Possible motor damaged by insufficient stiff construction of the machine due to a continuous and strong attractive force between primary and secondary part!**

Depending on the motor arrangement, the attractive forces must be accommodated by linear guides and the slide and machine structure.

When installed, the attractive force must not reduce the air gap between primary and secondary part. The mechanical design must provide sufficient rigidity.

☞ The attractive forces at nominal air gap are given in the data sheet of the respective motor in chapter 4 "Technical Data IndraDyn L" on page 17.

## 9.5.2 Air Gap-related Attractive Forces between Primary and Secondary Part

The attractive force rises as the distance between primary and secondary part is reduce.

When lowering the primary part on the secondary part, result by reducing the air gap increasing attractive forces.

The path in the following diagram shows the attractive force as a function of the air gap.

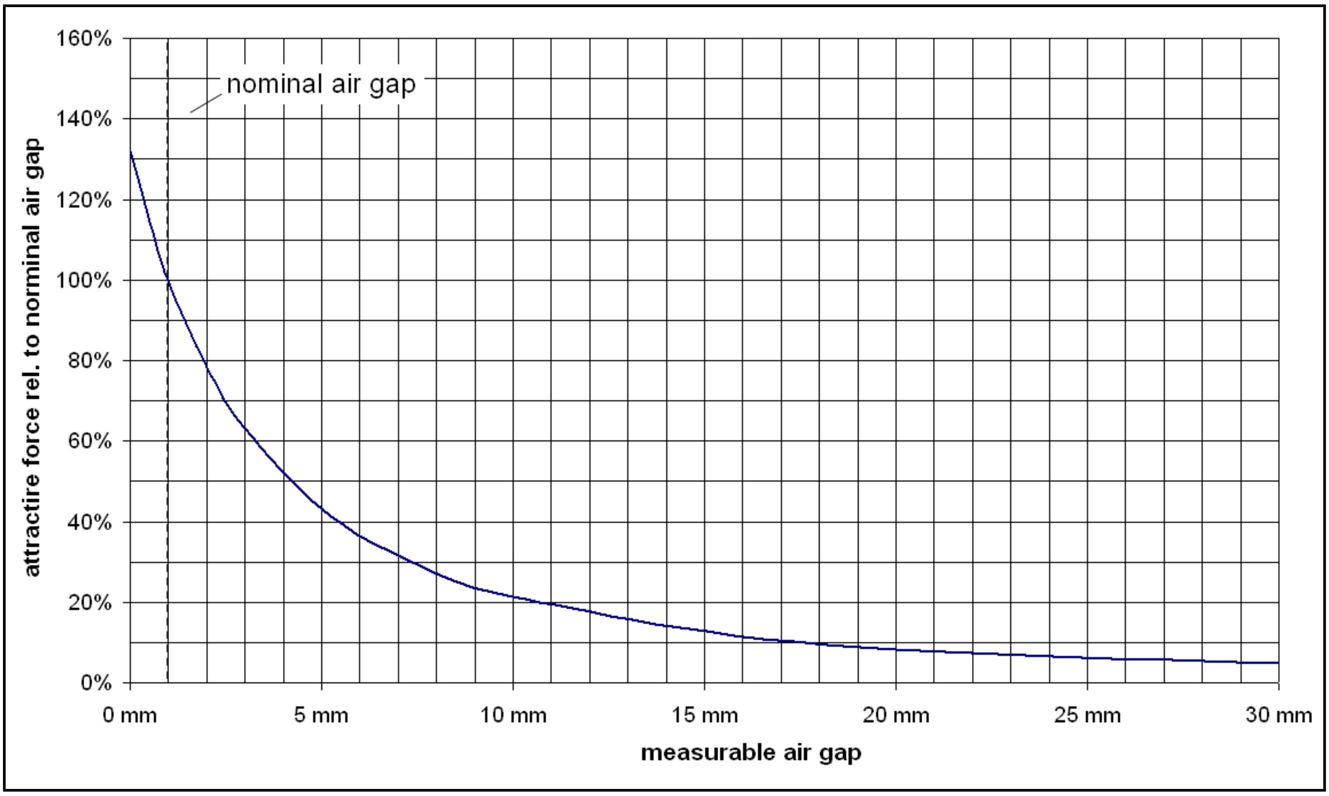
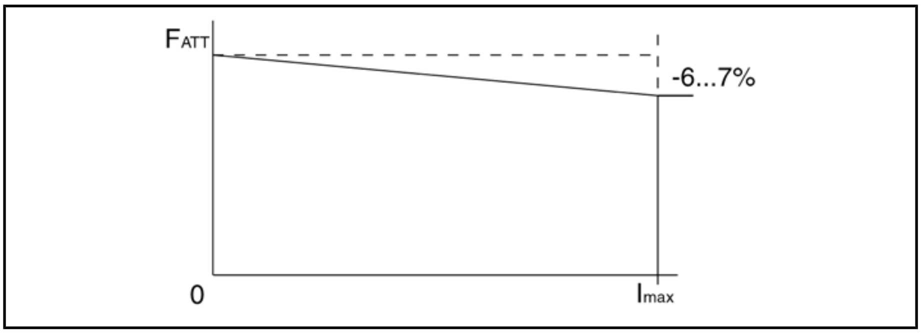



*Fig.9-30: Attractive force vs. distance between primary and secondary part*

## 9.5.3 Air Gap-related attractive Forces vs. Power Supply

The attractive force decreases with rising power supply of the primary part.

The path in the following diagram shows the attractive force vs. the power supply.




$F_{ATT}$ Attractive force

$I_{max}$ Maximum current

*Fig.9-31: Attractive force vs. power supply*

## 9.5.4 Air Gap-related Feed Force

**Air Gap Tolerances**

The feed force detailed in the specifications are related to the specified rated air gap. The tolerances permissible for the measurable air gap have a slight effect on the feed forces that can be achieved. The following diagram shows this relationship:

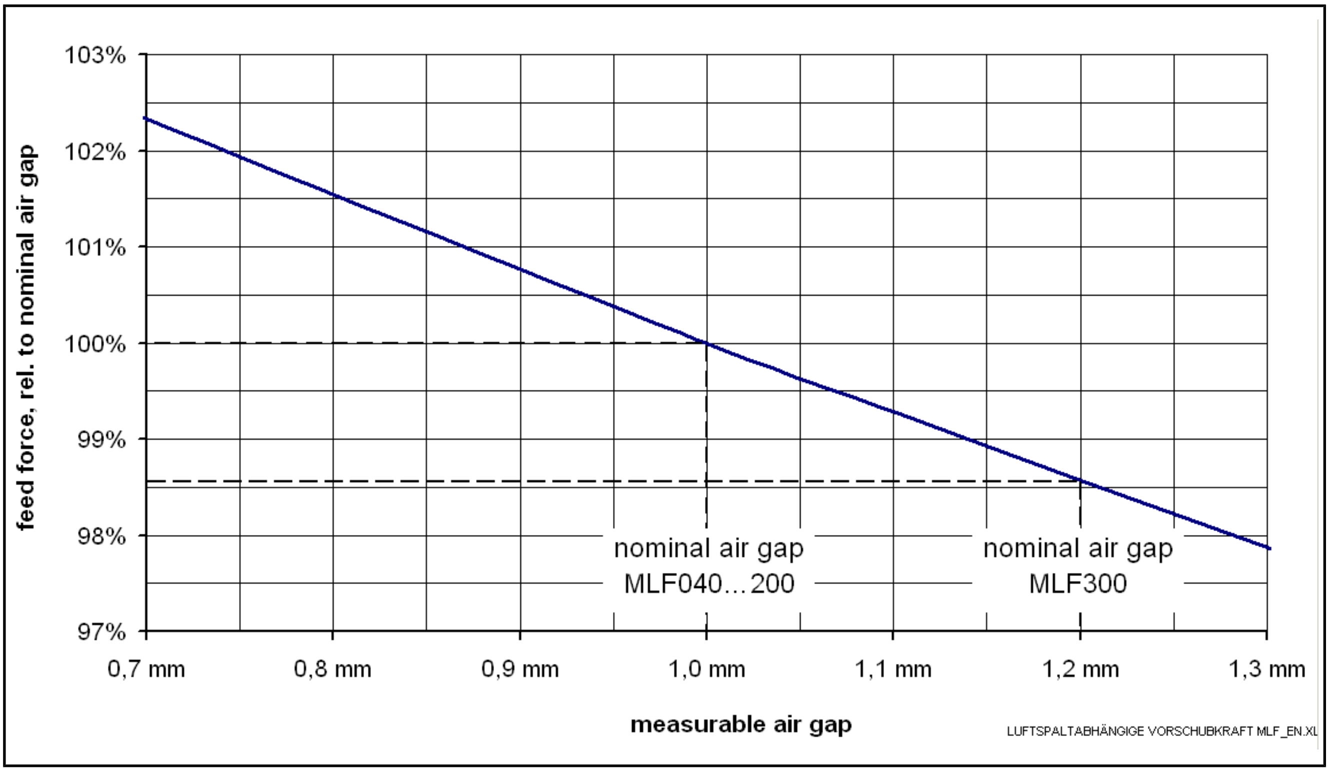



*Fig.9-32: Feed force within the air gap tolerance of synchronous linear motors IndraDyn L.*

The sizes in fig. 9-32 "Feed force within the air gap tolerance of synchronous linear motors IndraDyn L." on page 114 are only valid for IndraDyn L synchronous linear motors and there is no general correlation for other motor types.

## 9.5.5 Reduced overlapping between Primary and Secondary Part

When moving in the end position range of an axis, it can be necessary that the primary part moves beyond the end of the secondary part. This results in a partial coverage between primary and secondary part.

If primary and secondary part are only partially covered, follows a reduced feed force and attractive force.

**Inception of the Force Reduction**

The force reduction does not start immediately. It differs according to the encapsulation types and the installation position of the primary part.

Outside the beginning and end areas($s_{R1}$ or $s_{R2}$), the force is reduced linearly as a function of the reduced coverage area.

The following diagram illustrates the correlation between the coverage between primary and secondary part and the resulting force reduction.

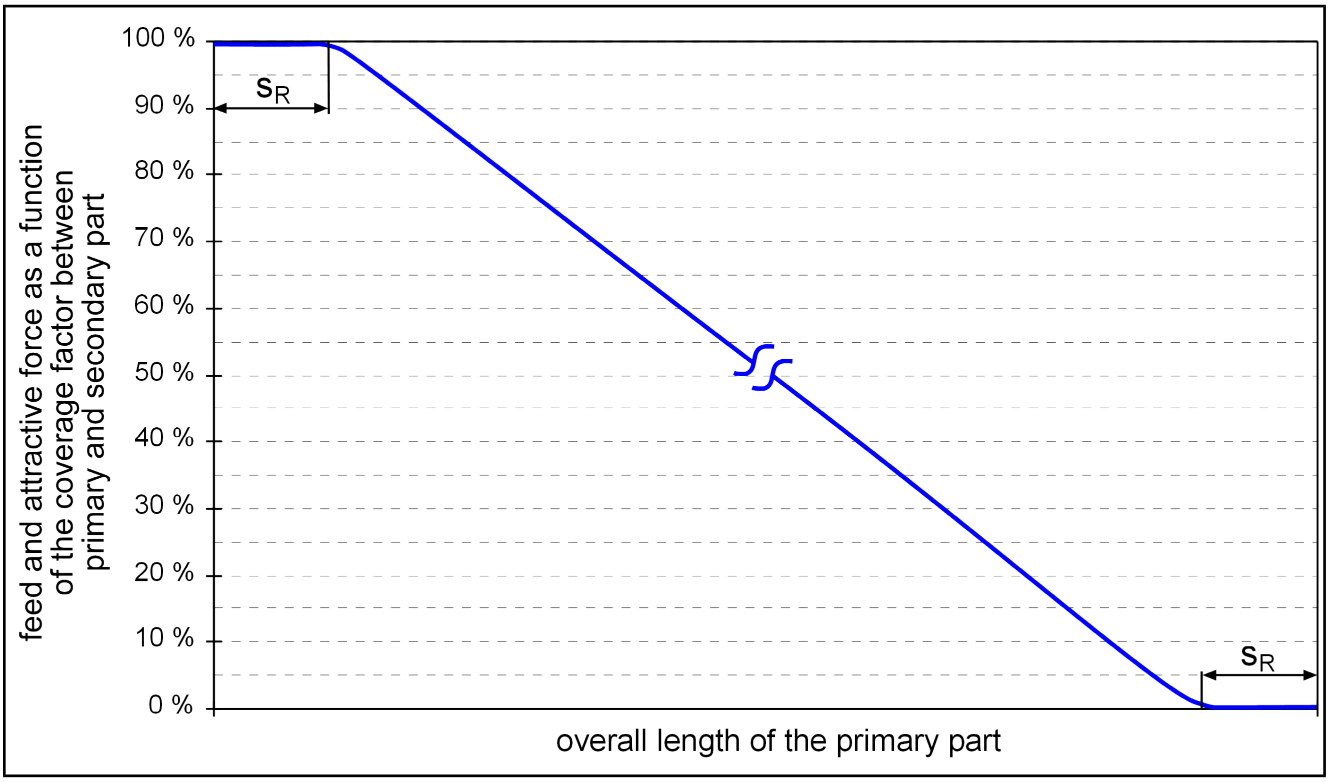



*Fig.9-33: Force reduction with partial coverage of primary and secondary part*

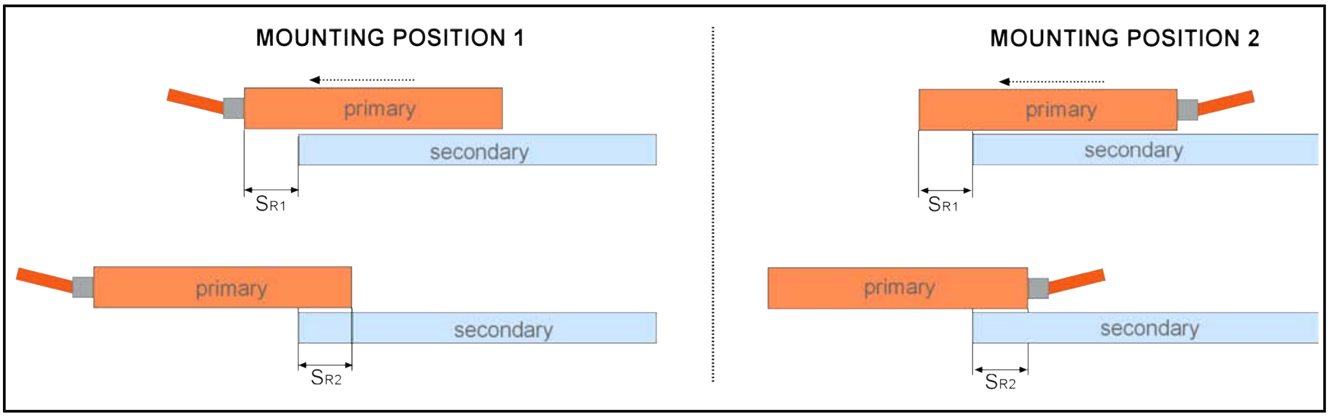



*Fig.9-34: Presentation of force reduction with regard to Fig. 9-33*

| Motor version | Installation position 1 | |
|---|---|---|
| | $S_{R1}$ [mm] | $S_{R2}$ [mm] |
| Standard encapsulation | 30 | 5 |
| Thermal encapsulation | 52 | 8 |
| | **Installation position 2** | |
| Standard encapsulation | 5 | 30 |
| Thermal encapsulation | 8 | 52 |

*Fig.9-35: Partial coverage vs. installation position*

The partial coverage of primary and secondary parts must not be used in continuous operation since there is an increased current consumption of the motor. Instabilities in the control loop can be expected from a certain reduction of the degree of coverage onwards.

**WARNING**

**Malfunctions and uncontrolled motor movements due to partial coverage of primary and secondary part!**

⇒ Partial coverage of primary and secondary part only when moving to the end position during a drive error

⇒ Minimum coverage factor 75%

# 9.6 Motor Cooling System

## 9.6.1 Thermal Behavior of Linear Motors

**Power Loss**

The rated feed force of a synchronous linear motor can be achieved is mainly determined by the power loss $P_V$ produced during the energy conversion process. The power loss fully dissipates in form of heat. Due to the limited permissible winding temperature it must not exceed a specific value.

☞ The maximum winding temperature of IndraDyn L motors is 155°C. This corresponds to insulation class F.

The total losses of synchronous linear motors are chiefly determined by the direct load loss of the primary part due to the low relative velocities between primary and secondary part:

$$P_V \approx P_{Vl} = \frac{3}{4} \cdot I^2 \cdot R_{12} \cdot f_T$$

| | |
|---|---|
| $P_V$ | Total loss in W |
| $P_{Vl}$ | Direct load losses in W |
| $I$ | Current in motor cable in A |
| $R_{12}$ | Electrical resistance of the motor at 20°C in Ohm (see Chapter 4 Technical Data) |
| $f_T$ | Factor temperature-related resistance raise |

*Fig.9-36: Power loss of synchronous linear motors*

☞ When you determine the power loss according to fig. 9-36 "Power loss of synchronous linear motors" on page 116 you must take the temperature-related rise of the electrical resistance into account. At a temperature rise of 115 K (from 20 °C up to 135 °C), for example, the electrical resistance goes up by the factor $f_T$ = 1.45.

**Thermal Time Constant**

The temperature variation vs. the time is determined by the produced power loss and the heat-dissipation and –storage capability of the motor. The heat-dissipation and –storage capability of an electrical machine is (combined in one variable) specified as the thermal time constant.

☞ With liquid cooling systems, the thermal time constant is between 5...10 min (depending on size).

The following figure (fig. 9-37 "Heating up and cooling down of an electrical machine" on page 117) shows a typical heating and cooling process of an electrical machine. The thermal time constant is the period within which 63% of the final over temperature is reached. With liquid cooling, the cooling time constant corresponds to the heating time constant. Thus, the heating process and the cooling process can both be specified with the specified thermal time constant (heating time constant) of the motor.

Together with the duty cycle, the correlation to fig. 9-38 "Heating up (over temperature) of an electrical machine compared with coolant" on page 117 and fig. 9-40 "Cooling down of an electrical machine" on page 118 are used for defining the duty type, e.g. acc. to DIN VDE 0530.

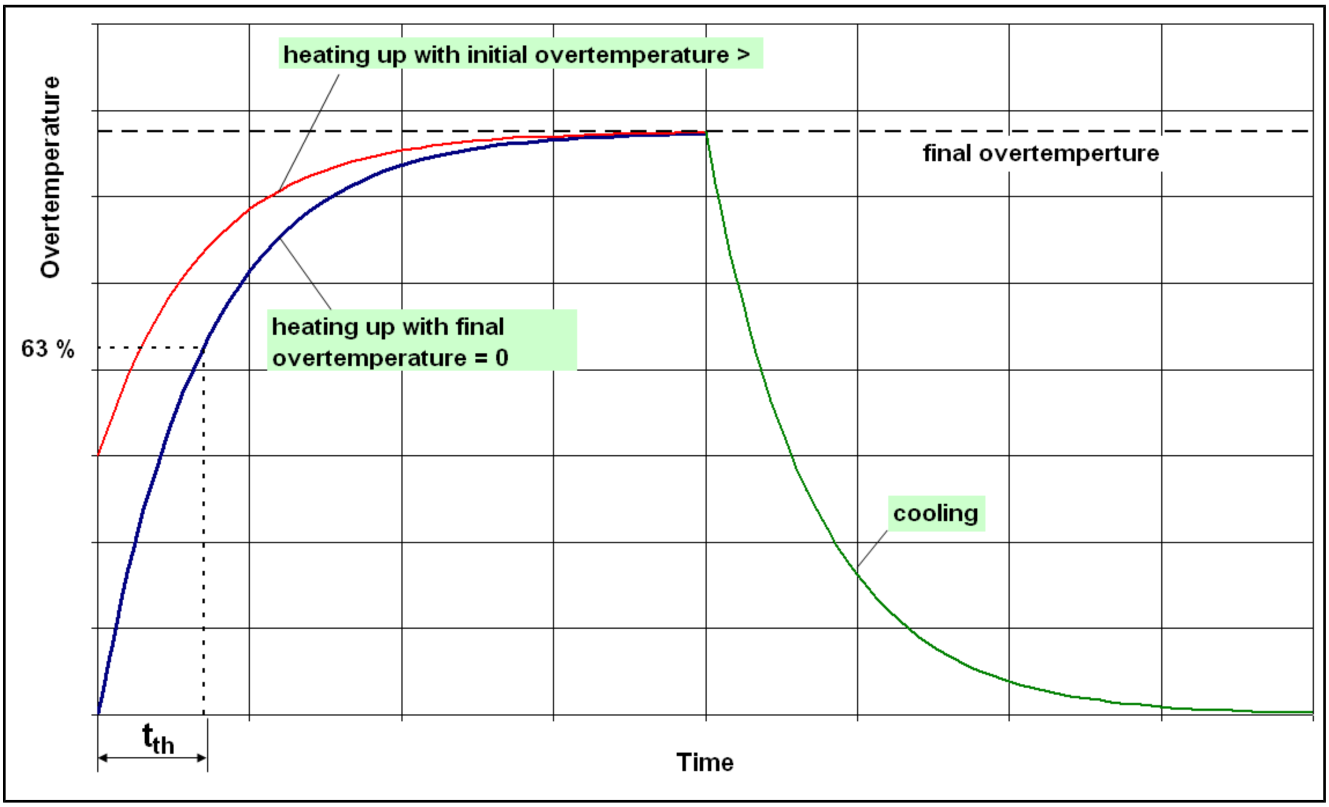



*Fig.9-37: Heating up and cooling down of an electrical machine*

**Heating Up**

$$\vartheta(t) = \vartheta_e \cdot \left(1 - e^{-\frac{t}{t_{th}}}\right) + \vartheta_a \cdot e^{-\frac{t}{t_{th}}}$$

| | |
|---|---|
| $\vartheta_e$ | Final over temperature in K |
| $\vartheta_a$ | Initial over temperature in K |
| t | Time in min |
| $t_{th}$ | Thermal time constant in min (see Chapter 4 ”Technical Data) |

*Fig.9-38: Heating up (over temperature) of an electrical machine compared with coolant*

**Final Over Temperature**

Since the final over temperature is proportional to the power loss, the expected final over temperature $\vartheta_e$ can be estimated according to fig. 9-39 "Expected final over temperature of the motor" on page 118:

$$\vartheta_e = \frac{P_{ce}}{P_{vN}} \cdot \vartheta_{emax} = \frac{F_{eff}^2}{F_{dN}^2} \cdot \vartheta_{emax}$$

| | |
|---|---|
| $P_{ce}$ | Permanent power loss or average power loss vs. duty cycle time in W (see Chapter 11.4 ”Determining the Drive Power) |
| $P_{vN}$ | Nominal power loss of the motor in W |
| $\vartheta_{emax}$ | Maximum final over temperature of the motor in K |
| $F_{eff}$ | Effective force in N (from application) |
| $F_{dn}$ | Rated force of the motor in N (see Chapter 4 ”Technical data”) |
| $t_{th}$ | Thermal time constant in min (see Chapter 4 ”Technical Data) |

*Fig.9-39: Expected final over temperature of the motor*

**Cooling Down**

$$\vartheta(t) = \vartheta_e \cdot e^{-\frac{t}{t_{th}}}$$

| | |
|---|---|
| $\vartheta_e$ | Final over temperature or shutdown temperature in K |
| t | Time in min |
| $t_{th}$ | Thermal time constant in min (see Chapter 4 ”Technical Data) |

*Fig.9-40: Cooling down of an electrical machine*

## 9.6.2 Cooling Concept of IndraDyn L Synchronous Linear Motors

The request for highest feed forces and minimum installation volume usually requires linear motors to be equipped with a liquid cooling. The liquid cooling ensures:

- that the power loss is removed and, consequently, rated feed forces are maintained;
- that a certain temperature level is maintained at the machine

The cooling and encapsulation concept of IndraDyn L motors contains two different solutions:

**Standard Encapsulation**

Primary parts with standard encapsulation are mainly used in the general automation sector. The cooling system of this motor design is integrated into the motor and can only be used to discharge lost heat or keeping the specified continuous feedrate. It offers no additional thermal decoupling on the motor side to the machine. The maximum temperature of the contact surface can locally rise up to 60 °C. These maximum temperature gradients can occur independently of the coolant inlet temperature.

**Thermal Encapsulation**

For an optimum thermal decoupling between the motor and the machine structure, the primary parts of the thermal encapsulation version have an additional liquid cooling system at the back of the motor and at longitudinal and frond ends. The constant temperature that can easily be attained and the minimum heat transfer into the machine make the primary parts of the thermal encapsulation version particularly suitable for the utilization in machine tools and in other precision applications. Inside the motor there is already an optimum connection between the internal cooling circulation used for removing the power loss and the cooling ducts of the thermal encapsulation.

The primary part is not completely connected with the mounting surface on the machine side, but only lays on increased bearing points. This provides an additional thermal decoupling and, consequently, further minimization of the possible heat transfer into the machine (see fig. 9-41 "Cooling concept for thermal encapsulation" on page 119).

Using the thermal encapsulation does not provide any improved performance date, e.g. for the continuous feed force. The power ratings are identical for both versions.

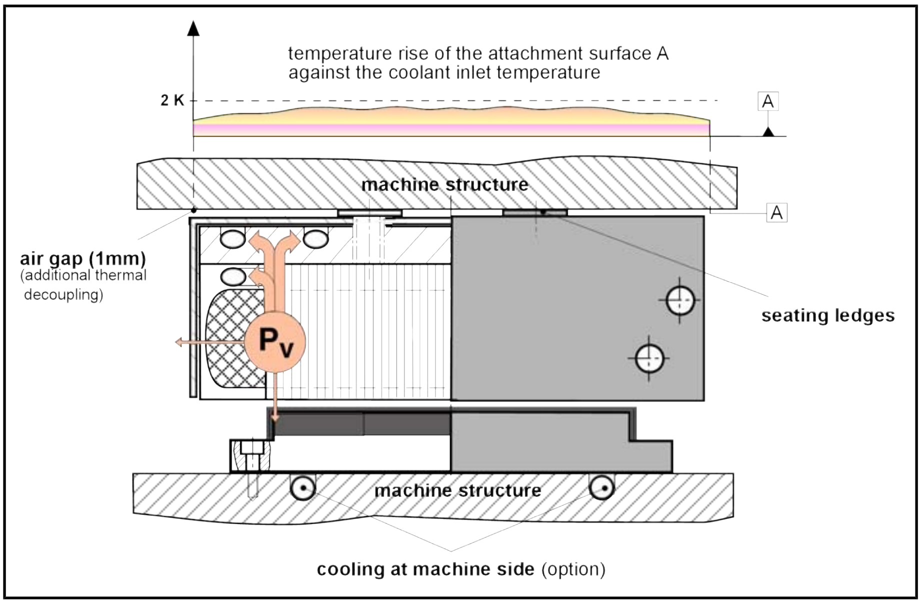



*Fig.9-41: Cooling concept for thermal encapsulation*

**Secondary Parts**

The secondary version is identical for both primary part versions. The secondary part does not develop any power loss. With inadvertent conditions (extended standstill or slow velocity of the primary part together with a simultaneously acting high continuous force), there can be a heat transfer by the primary part due to radiation or convection.

The secondary part does not develop any power loss. The maximum heat infiltration possible of the primary part at standstill and continuous nominal force is approximately 3% of the motor´s nominal power loss.

The heat transfer depends on the ambient temperature and on the installation conditions in the machine.

To maintain a constant temperature level in the machine, cooling can be done at the machine side, e.g. via two cooling pipes (seefig. 9-41 "Cooling concept for thermal encapsulation" on page 119).

## 9.6.3 Coolant Medium

### General Information

The specified motor data and the characteristics of the motor cooling system (e.g. continuous feed forces, pressure losses, and flow characteristics), and all the other specifications in this Chapter are related to liquid cooling with coolant water. Most cooling devices use water, too.

The following coolants can be used:

- Water
- Oil
- Air

☞ The specified motor data and the characteristics of the motor cooling system (e.g. continuous feed forces, pressure losses, and flow characteristics), and all the other specifications in this Chapter are related to liquid cooling with coolant water.

This data is no longer valid and must again be calculated or determined empirically if coolants with different material characteristics are used.

An impairment of the thermal decoupling may also have to be taken into account, if necessary.

WARNING

**Impairing the cooling effect of damaging the cooling system!**

⇒ Adjust coolant and flow to the required motor performance data

⇒ With coolant water use anticorrosion agent and observe the specified mixture and the pH-value.

⇒ Use approved anticorrosion agents, only

⇒ Do not use cooling lubricants from machining process

⇒ Filter the coolant medium

⇒ Do not use flowing water

⇒ Use a closed cooling circuit

⇒ Adhere to the specified inlet temperatures

⇒ Keep the maximal pressure

⇒ Motor operation not without liquid cooling

A cooling with floating water from the supply network is not admissible. Calcareous water can cause deposits or corrosion and damage the motor and the cooling system. Water used as cooling water has to meet certain criteria and, if applicable, has to be treated accordingly. You will get detailed information from your manufacturer for coolant additives.

☞ **Danger of damage due to unsufficient water quality in the coolant circuit!**

Deposits within the cooling system can reduce the coolant flow and thereby reduce the power of the cooling system.

Please make sure that the used water has the following characteristics:

- pH-value: 7 ... 8,5
- Grade of hardness: 10° dH
- Chloride: max. 20 mg / l
- Nitrate: max. 10 mg / l
- Sulfate: max. 100 mg / l
- Insolulble substances: max. 250 mg / l

Normally, tap water meets these demands.

Observe further notes regarding suitable consistence of the coolant.

**pH-Value**

Not only the mixture, but also the pH-value of the used coolant must be checked in suitable distances. The coolant should be chemically neutral. Larger deviations can lead to changes in the stability of the emulsion, the behavior towards sealant, and the corrosion protection capability.

**Corrosion Protection**

For corrosion protection and for chemical stabilization, the cooling water has to have an additive suitable for mixed-installations with the materials steel or iron, aluminum, copper and brass.

Use of too aggressive coolants, additives, or cooling lubricants can cause irreparable motor damages.

- Use systems with a closed circulation and a fine filter ≤ 100 µm.
- Observe the environmental protection and waste disposal instructions at the place of installation when selecting the coolant.

**Cleaning the Coolant Circuit**

Inspect and clean (purge) the cooling system in regular intervals as specified in the maintenance plan of the machine and cooling system manufacturer respectively.

Note that the utilization of unsuitable cleaning agents may irreparably damage the motor cooling system. This type of damages does not lie within the responsibility of Bosch Rexroth.

---

CAUTION

**Risk of damage to the motor cooling system by unsuitable cleaning agents! Invalidation of warranty!**

⇒ For cleaning and motor cooling, only liquids or agents must be used that do not corrode the motor cooling system and do not react aggressively to the materials used in our motors.

⇒ Observe the information by the manufacturers of the cleaning agent and the cooling system.

---

☞ After operation of the motor, e.g. in case of storage or return, the coolant must be removed completely out of the motor for environmental and motor protection reasons.

## Coolant Additives

## Coolant Additives

**Recommended Manufacturers of Coolant Additives**

The proper chemical treatment of the closed water systems is precondition to prevent corrosion, to maintain thermal transmission, and to minimize the growth of bacteria in all parts of the system.

Bosch Rexroth recommends using coolant additives of the company NALCO Deutschland GmbH.

Depending on the size of the cooling system, the user may use different additives in form of "ready-to-use cooling water" and "water treatment kits".

☞ The packaging size and the ingredients of the water treatment kit are completely adapted to the corresponding system volume and the user may fill them into the coolant reservoir without observing further mixing ratios.

**Ready-to-use cooling water (company NALCO)**

| System volume in liters | Ordering designation | Additives NALCO... |
|---|---|---|
| 0,5 ... 50 | Nalco PCCL100.11R | PCCL100 |

*Fig.9-42: Ready-to-use cooling water (company NALCO)*

**Coolant Water NALCO PCCL100**

Nalco PCCL100 is a ready-to-use, preserved cooling water for the use in closed cooling water systems. It is supplied directly to the closed systems and contains all reagents in the propter treatment concentration.

Nalco PCCL100 contains a corrosion inhibitor protecting iron, copper, copper alloys and aluminum against corrosion. Nalco PCCL100 is free of nitrite and minimizes the micro-biological growth.

**Water treatment kits (company NALCO)**

| System volume in liters | Ordering designation | Additives NALCO... |
|---|---|---|
| 50 ... 100 | 480-BR100-100.88 | TRAC100<br>7330<br>73199 |
| 100 ... 200 | 480-BR100-200.88 | |
| 200 ... 350 | 480-BR100-350.88 | |
| 350 ... 500 | 480-BR100-500.88 | |

*Fig.9-43: Water treatment kits (company NALCO)*

**Coolant Additive NALCO TRAC100**

Nalco TRAC100 is a liquid corrosion and film inhibitor for the use in closed cooling systems. Optionally with TRASAR technology: it monitors, shows and dosages the product automatically to its target concentration and continuously protects the system. NALCO TRAC100 is a complete inhibitor protection iron metal, copper alloys and alumnum against corrosion. NALCO TRAC100 is free of nitrite and minimizes the requirements for micro-biological control.

**Coolant additive NALCO 7330**

Nalco 7330 is a non-oxidizing broad band biocide and suiteable for application in closed cooling circuit systems.

**Coolant additive NALCO 73199**

Nalco 73199 is an organic corrosion inhibitor supporting a fast own protection layer and covering protection layer for non-ferrous metals.

The above additives are part of the preventive water treatment program by Nalco. It comprises not only the chemicals but also test methods, service and equipment. All these are made available to the user of the products.

The water treatment program is a specification for the user and describes the minimum requirements. Consult Nalco on any additional equipment, tests and services to ensure optimum performance and system protection of the cooling systems.

For additional information and order placement, please contact:

**NALCO Deutschland GmbH**

Plankstr. 26

71691 Freiberg/Neckar, Germany

Fax +49(0)7141-703-239

slund@nalco.com

www.nalco.com

☞ Bosch Rexroth is not in a position to give general statements or carry out investigations regarding applicability of process-related coolants, additives, or operating conditions.

The performance test for the used coolants and the design of the liquid coolant system are generally the responsibility of the machine manufacturer.

## Coolant Temperature

**Temperature Range**

The recommended coolant inlet temperature range is at +15... +40°C. The adjustable coolant inlet temperature depends from the existing ambient temperature and should be maximum 5 K lower than the measured ambient temperature.

An overstepping of the recommended temperature range leads to a stronger reduction of the continuous feed force.

☞ The coolant inlet temperature should be maximum 5 K lower than the actual existing room temperature to avoid condensation.

WARNING

**Reduction of the continuous feed force of destruction of the motor!**

⇒ Keep coolant within permissible temperature range

**Continuous Feed Force vs. Coolant Temperature**

The specification of the rated feed force in the technical motor specifications is related to a coolant inlet temperature of 30 °C.

If the inlet temperature is different, there is a minor change of the continuous feed force according to Continuous feed force vs. coolant flow temperature:

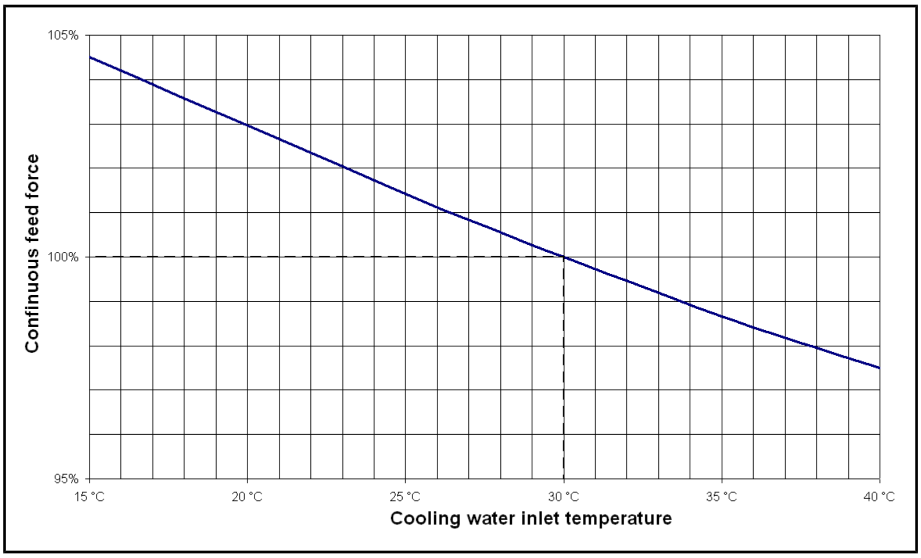



*Fig.9-44: Continuous feed force vs. coolant flow temperature*

## Maximum Pressure

With all motor versions, the maximum system pressure via the internal system circulation of the motor is **10 bar**.

Pressure fluctuations within the cooling circuit should not exceed **± 1 bar** during motor operation. Beyond pressure fluctuations or pressure peaks are not permitted!

WARNING

**Motor destruction!**

⇒ Keep coolant within permissible inlet pressure.

⇒ Incorrect pressure fluctuations and pressure peaks have to be excluded via constructive measures.

## 9.6.4 Operation of IndraDyn L Synchronous Linear Motors without Liquid Cooling

Theoretically an operation of IndraDyn T-motors without any liquid coolant is possible.

Therefore, please heed the following restrictions:

- Without liquid coolant only **reduced power data** are available. These are listed in this documentation.

- The stated values in the data sheets regarding rated force and rated current of the motors must be lowered depending on the coupling of the motors to **~40 %** of the stated value.
- A higher temperature load of the machine can be expected This results in an extension of the nominal air gap, which is stated in the particular data sheets of the motors. It must be extended by 0.2 mm.

It does not reduce the available maximum force of the motors.

Depending on the load, the temperature at the contact surface of the primary part may rise up to 140%C without liquid cooling. The power loss of the motors is dissipated over the screw-surface and the machine construction on the customer side.

---

**WARNING**

**Drastic reduction of the rated feed force and significant heating and stress of the machine structure if synchronous linear motors are used without liquid cooling!**

⇒ Provide liquid cooling

⇒ The reduction of the rated force and the heating of the machine structure (stress due to expansion) must be included in the sizing and design of axes that are used without liquid cooling.

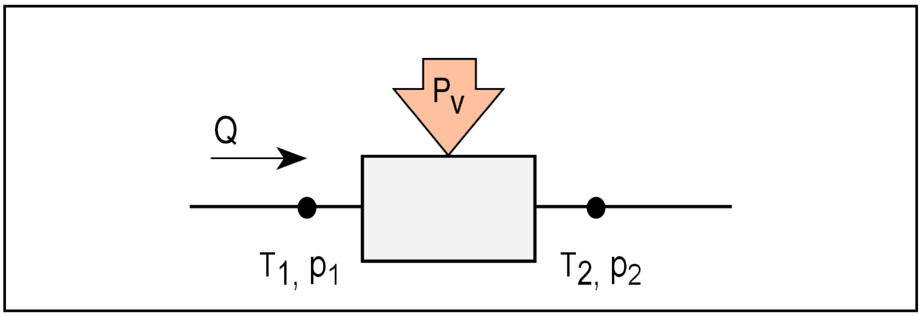
⇒ Reduce the current over the parameter S-0-0111 on the non-water cooled motor when start-up! Without a reduction of the rated current, the motor heats up so fast that the thermal contacts cannot switch off the motor in every case on time. An overheated winding is the consequence. Due to the overheated winding, the winding insulation is weak or in an extreme case destroyed.

---

☞ Therefore, note the details about parameterization within chapter 14.4 "Parameterization " on page 229 about operating an IndraDyn L synchronous linear motor withour liquid cooling.

## 9.6.5 Sizing the Cooling Circuit

### General Information




| | |
|---|---|
| Q | Flow quantity |
| $T_1$ | Coolant inlet temperature |
| $T_2$ | Coolant outlet temperature |
| $p_1$ | Inlet pressure |
| $p_2$ | Outlet pressure |

*Fig.9-45: Liquid-cooled component*

**Coolant Temperature Rise**

$$\Delta T = T_2 - T_1$$

| | |
|---|---|
| $T_1$ | Coolant inlet temperature in K |
| $T_2$ | Coolant outlet temperature in K |
| $\Delta T$ | Coolant temperature rise in K |

*Fig.9-46: Coolant temperature rise in K*

**Pressure Drop**

$$\Delta p = p_1 - p_2$$

| | |
|---|---|
| $p_1$ | Inlet pressure |
| $p_2$ | Outlet pressure |
| $\Delta p$ | Pressure drop |

*Fig.9-47: Pressure drop across traversed component*

**Design Criteria**

Related to the motor, two basic application-related requirements must be distinguished when the cooling circuit of synchronous linear motors is sized.

1. Liquid cooling is only used for removing the power loss and thus for maintaining the specified rated forces (e.g. for standard encapsulation motor version)
2. At the same time, liquid cooling shall ensure a defined temperature level at the contact surface (e.g. for the thermal encapsulation motor version).

## Flow Quantity

**Coolant Flow to maintain the Rated Feed Force**

Rexroth recommends to dimension the coolant flow for motors up to size 070 to ~ 5 l/min, for size 100 to ~ 6 l/min.

The minimum coolant flow required to maintain the rated feed force is defined in Chapter 4 ”Technical Data”.

The specification of this value is based on a rise of the coolant temperature by 10 K.

fig. 9-48 "Coolant flow required for removing a given power loss." on page 125 and fig. 9-49 "Substance values of different coolants at 20°C" on page 125 are used to determine the necessary coolant flow at different temperature rises and / or different coolants:

$$Q = \frac{P_{co} \cdot 60000}{c \cdot \rho \cdot \Delta T}$$

| | |
|---|---|
| $Q$ | Rated coolant flow in l/min |
| $P_{co}$ | Removed power loss in W |
| $c$ | Specific heat capacity of the coolant in J / kg · K |
| $\rho$ | Density of the coolant in kg/m³ |
| $\Delta T$ | Coolant temperature rise in K |

*Fig.9-48: Coolant flow required for removing a given power loss.*

| Coolant | Specific heat capacity of the coolant in J / kg · K | Density ρ in kg/m³ |
|---|---|---|
| Water | 4183 | 998,3 |
| Thermal oil (example) | 1000 | 887 |
| Air | 1007 | 1,188 |

*Fig.9-49: Substance values of different coolants at 20°C*

**Maintaining a Constant Temperature Level at Thermal Encapsulation**

If you want to ensure a defined temperature level at the contact surface of the primary part of the thermal encapsulation motor version, you must use the formula acc. to fig. 9-50 "Coolant flow required for maintaining a constant temperature level at the motor contact surface in the case of thermal encapsulation" on page 126 to determine the coolant flow that is necessary for maintaining a maximum coolant temperature rise. It is to be taken into account that only a part of the power loss remains to be removed via the thermal encapsulation. $\Delta T_m$ is the temperature at the contact surface of the primary part.

A defined temperature level at the contact surface can only be maintained with the thermal encapsulation motor version.

$$Q = \frac{P_{co} \cdot 25200}{c \cdot \rho \cdot \Delta T_m}$$

| | |
|---|---|
| Q | Rated coolant flow in l/min |
| $P_{co}$ | Removed power loss in W |
| c | Specific heat capacity of the coolant in J / kg · K |
| ρ | Density of the coolant in kg/m³ |
| $\Delta T_m$ | Temperature rise on contact surface in K |

*Fig.9-50: Coolant flow required for maintaining a constant temperature level at the motor contact surface in the case of thermal encapsulation*

**Prerequisites:** $Q \geq Q_{min}$ (see chapter 4 ”Technical Data”)

## Pressure Drop

The flow resistance at the pipe walls, curves, and changes of the cross-section produces a pressure drop along the traversed components (fig. 9-45 "Liquid-cooled component" on page 124).

The pressure drop Δp rises as the flow quantity rises (fig. 9-51 "Pressure drop vs. flow quantity; general representation" on page 126).

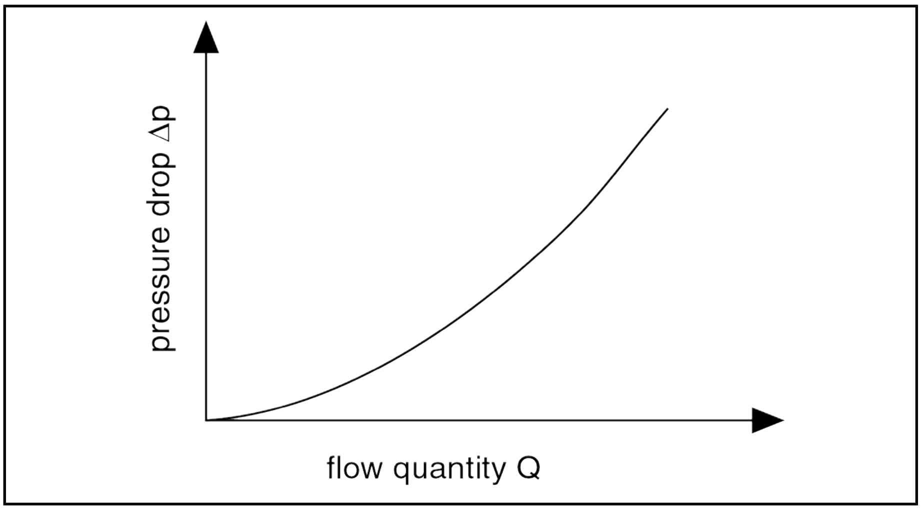



*Fig.9-51: Pressure drop vs. flow quantity; general representation*

**Pressure Drop across the Motor Cooling System**

On the basis of the constant for determining the pressure drop $k_{dp}$ that is explained in Chapter 4 ”Technical Data”, the pressure drop across the internal motor cooling circuit can be determined as follows:

$$\Delta p_m = k_{dp} \cdot Q^{1.75}$$

| | |
|---|---|
| $\Delta p_m$ | Pressure drop across the internal motor cooling circuit in bar |
| Q | Flow quantity in l/min |
| $k_{dp}$ | Constant for determining the pressure drop (see Chapter 4 ”Technical data”) |

*Fig.9-52: Determining the pressure drop vs. the flow quantity*

**Overall Pressure Drop**

The pressure drop across the total system is determined by the sum of a series of partial pressure drop (fig. 9-53 "General arrangement of a liquid cooled motor with heat removal facility" on page 127). Usually, the pressure drop across the internal motor cooling system is relatively small.

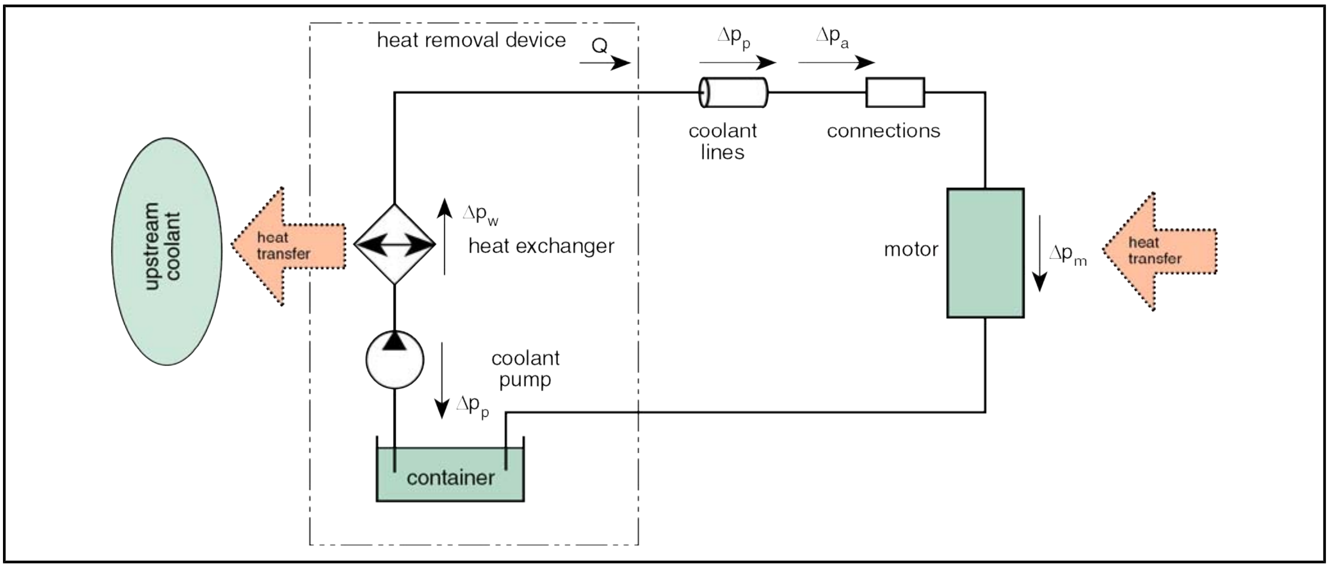



*Fig.9-53: General arrangement of a liquid cooled motor with heat removal facility*

☞ The overall pressure drop of the cooling system is determined by various partial pressure drops (motor, feeders, connectors, etc.). This must be taken into account when the cooling circuit is sized.

## 9.6.6 Liquid Cooling System

### General Information

Machines and systems can require liquid cooling for one or more working components. If several liquid-cooled drive components exist, they are connected to the heat removal device via a distribution unit.

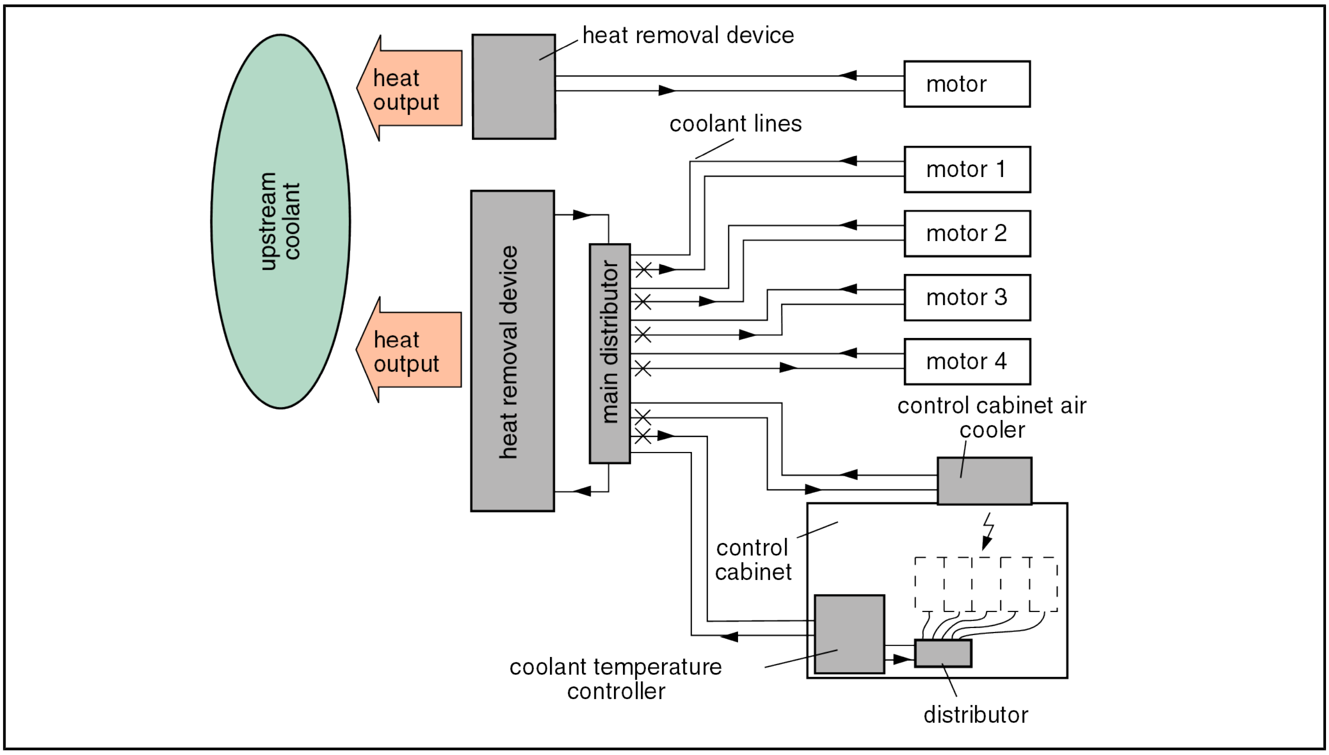



*Fig.9-54: General arrangement of cooling systems with one and more drive components*

**Heat Removal Device**

The heat removal device carries off the total heat that was fed into the liquid into a superordinate coolant. It provides a temperature-controlled coolant and thus maintains a required temperature level at the components that are to be cooled.

A heat removal device includes a heat exchanger, a coolant pump container and a coolant container.

There are three different types of heat removal devices. They are identified by the type of the heat exchanger between the different media:

1. **Air-to liquid cooling unit**
2. **Liquid-to-liquid cooling unit**
3. **Cooling unit**

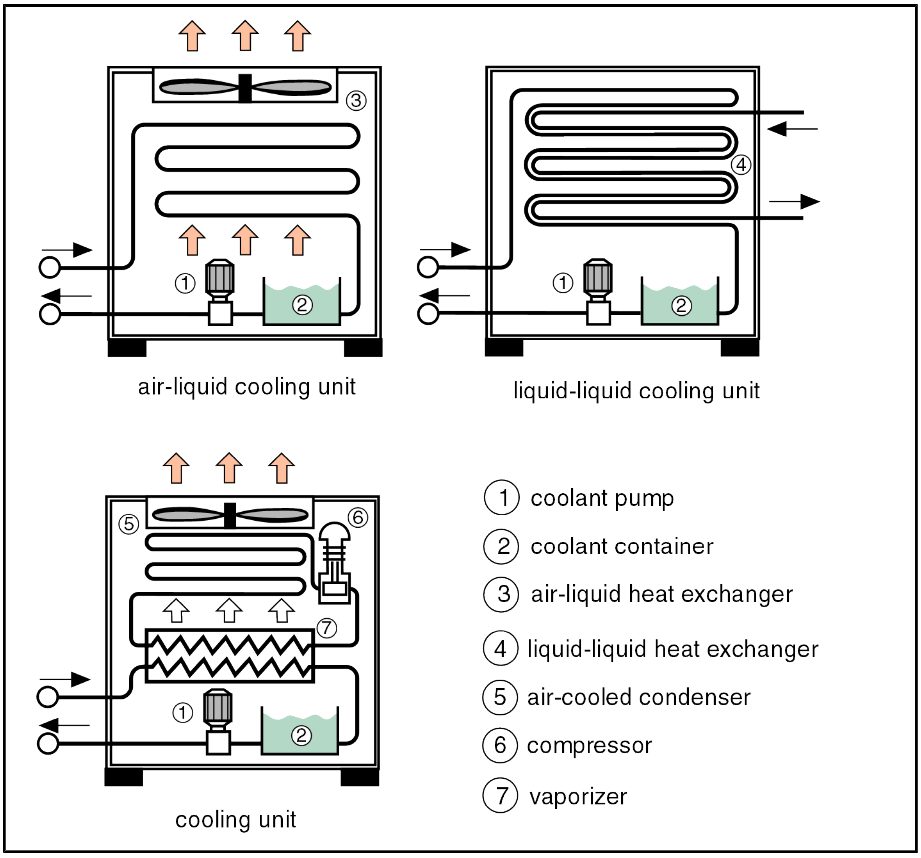



*Fig.9-55: Heat removal devices*

| | Air-to liquid cooling unit | Liquid-to-liquid cooling unit | Cooling unit |
|---|---|---|---|
| Coolant temperature control accuracy | Low (±5 K) | Low (±5 K) | Good (±1 K) |
| Superordinated coolant circuit required | No | Yes | No |
| Heating of ambient air | Yes | No | Yes |
| Power loss recovery | No | Yes | No |
| Size of the cooling unit | Small | Small | Large |
| Dependent of ambient temperature | Yes | No | No |
| Environment-damaging coolant | No | No | Yes |
| Notes on utilization criteria | Particularly suitable for stand-alone machines that do not have a superordinated coolant circuit available and do not have to fulfill high requirements on the stability of the coolant temperature. | This cooling type is particularly suitable for systems with existing central feedback cooler. It does fulfill high requirements on the stability of the coolant temperature. | Particularly suitable for high requirements on the thermal stability (high-precision applications, for example). |

*Fig.9-56: Overview of the heat removal devices according to utilization criteria*

## Coolant Duct

The coolant lines are a major part of the cooling system. They have a great influence on the system´s operational safety and pressure drop. The lines can be made up as hoses or pipes.

**Laying Flexible Coolant Lines within the Energy Chain**

The coolant lines of linear motor drives with moved primary parts must be laid within a flexible energy chain.

The continuous bending strain of the coolant lines must always be taken into account when they are sized and selected.

## Further optional components

- Distributions
- Coolant temperature controller
- Flow indicator

  r
  A message is output when the flow drops below a selectable minimum flow quantity.
- Level monitor

  Chiefly minimum-maximum level monitor to check the coolant level in the coolant container
- Overflow valve
- Safety valve

  Opens a connection between the coolant inlet and tank when a certain pressure is reached
- Coolant filter (100 µm)
- Coolant heating

  To provide coolant of a correct temperature, in particular for coolant temperature control
- Restrictor and shut-off valves

## Circuit types

The two possible ways of connecting hydraulic components (series/parallel connection) show significant differences with respect to:

- Pressure drop of the entire cooling system
- Capacity of the coolant pump
- Temperature level and controllability of the individual components that are to be cooled

**Parallel connection**

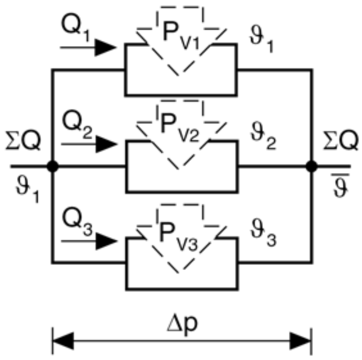



*Fig.9-57: Parallel connection of liquid-cooled drive components*

The parallel connection is characterized by nodes in the hydraulic system. The sum of the coolant streams flowing into a node is equal to the sum of the coolant streams flowing out of this node. Between two nodes, the pressure difference (pressure drop) is the same for all intermediate cooling system branches.

$$Q = Q_1 + Q_2 \quad ... + Q_n$$

$$\Delta p = \Delta p_1 = \Delta p_2 = \Delta p_n$$

Δp Pressure drop
Q Flow quantity

*Fig.9-58: Pressure drop and flow quantity in the parallel connection of hydraulic components*

When several working components are cooled, a parallel connection is advantageous for the following reasons:

- The individual components that are to be cooled can be cooled at the individual required flow quantity. This means a high thermal operational reliability.
- Same temperature level at the coolant entry of all components (equal machine heating) (uniformly machine heating)
- Same pressure difference between coolant entry and outlet of all components (no high overall pressure required)

**Series connection**

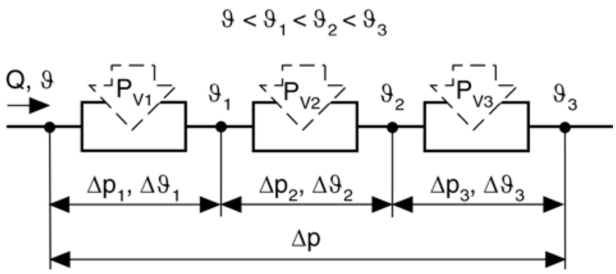



*Fig.9-59: Series connection of liquid-cooled drive components*

In series connection, the same coolant stream flows through all components that are to be cooled. Each component has a pressure drop between coolant inlet and coolant outlet. The individual pressure drops add up to the overall pressure drop of the drive components.

Series connection does not permit any individual selection of the flow quantity required for the individual components to be made. It is only expedient if the individual components that are to be cooled need approximately the same flow quantity and bring about only a small pressure drop or if they are installed very far away from the heat removal device.

$$Q = Q_1 = Q_2 = Q_n$$

$$\Delta p = \Delta p_1 + \Delta p_2 \quad \ldots \quad + \Delta p_n$$

| | |
|---|---|
| Δp | Pressure drop |
| Q | Flow quantity |

*Fig.9-60: Pressure drop and flow quantity in the parallel connection of hydraulic components*

The following disadvantages of series connection must always be taken into account:

- The required system pressure corresponds to the sum of all pressure drops of the individual components. This means a reduced hydraulic operational safety due to a high system pressure.
- The temperature level of the coolant rises from one component to the next. Each power loss contribution to the coolant rises its temperature (inhomogeneous machine heating)
- Some components may not be cooled as required since the flow quantity cannot be selected individually.

**Combination of Series and Parallel Connection**

Combining series and parallel connections of the drive components that are to be cooled permits the benefits of both connection types to be used.

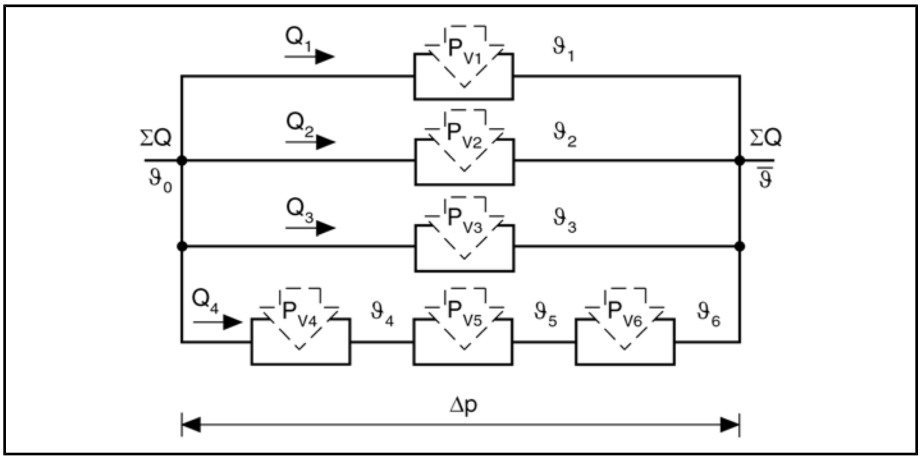



*Fig.9-61: Combination of series and parallel connection*

# 9.7 Motor Temperature Monitoring

In their standard configuration, primary parts of IndraDyn L motors are equipped with built-in motor protection temperature sensors. Every motor phase contains of one out of three switched in a row ceramic PTC´s, so that a sure thermical control of the motor in every operation phase is possible. These thermistors (furthermore: thermistor motor protection) have a switching character (fig. 9-65 "Characteristik of temperature sensors motor protection (PTC)" on page 134) and become evaluated on all Bosch Rexroth control devices.

Furthermore all primary parts are fitted with an additional thermistor for external temperature measurement. These sensors (furthermore: sensor temperature measurement) has nearly a linear characteristic curve (fig. 9-66 "Characteristic of temperature measurement sensor KTY84-130 (PTC)" on page 134).

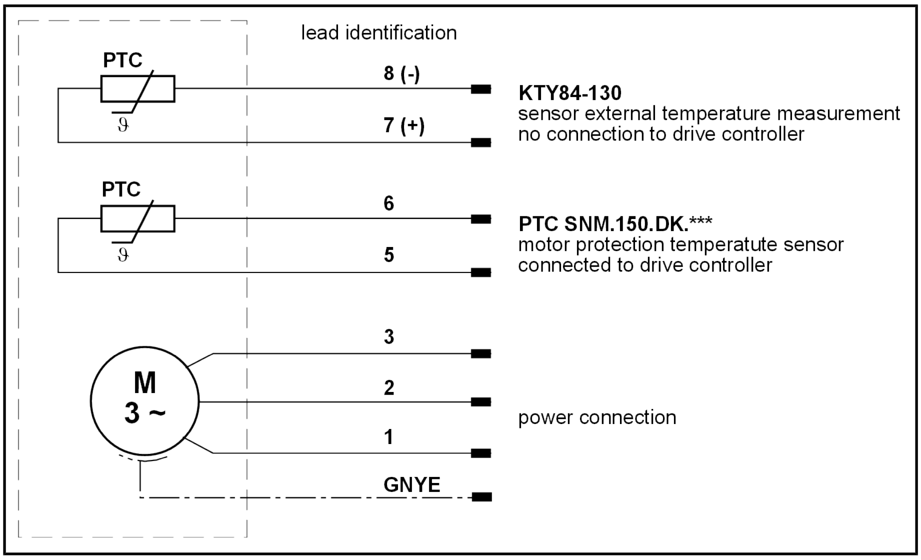



*Fig.9-62: Arrangement of temperature sensors at IndraDyn L motors*

**Temperature Sensor Motor Protection**

| Type | PTC SNM.150.DK.*** |
|---|---|
| Nominal operating temperature $\vartheta_{NAT}$ | 150 °C |
| Resistor at 25 °C | ≈ 100 ... 250 Ohm |

*Fig.9-63: Temperature sensor motor protection*

For the parallel arrangement of two or more primary parts, the motor protection temperature sensors of all primary parts are connected in series. For further details, please see Chapter 8 ”Electrical Connection”.

**Sensors Temperature Measurement External**

| Type | KTY84-130 |
|---|---|
| Resistor at 25 °C | 577 Ohm |
| Resistor at 100 °C | 1,000 Ohm |
| Continuous current at 100 °C | 2 mA |

*Fig.9-64: Sensor temperature measurement*

Notice the correct polarity when using the sensor for temperature measurement external (fig. 9-62 "Arrangement of temperature sensors at IndraDyn L motors" on page 133).

Application and Construction Instructions

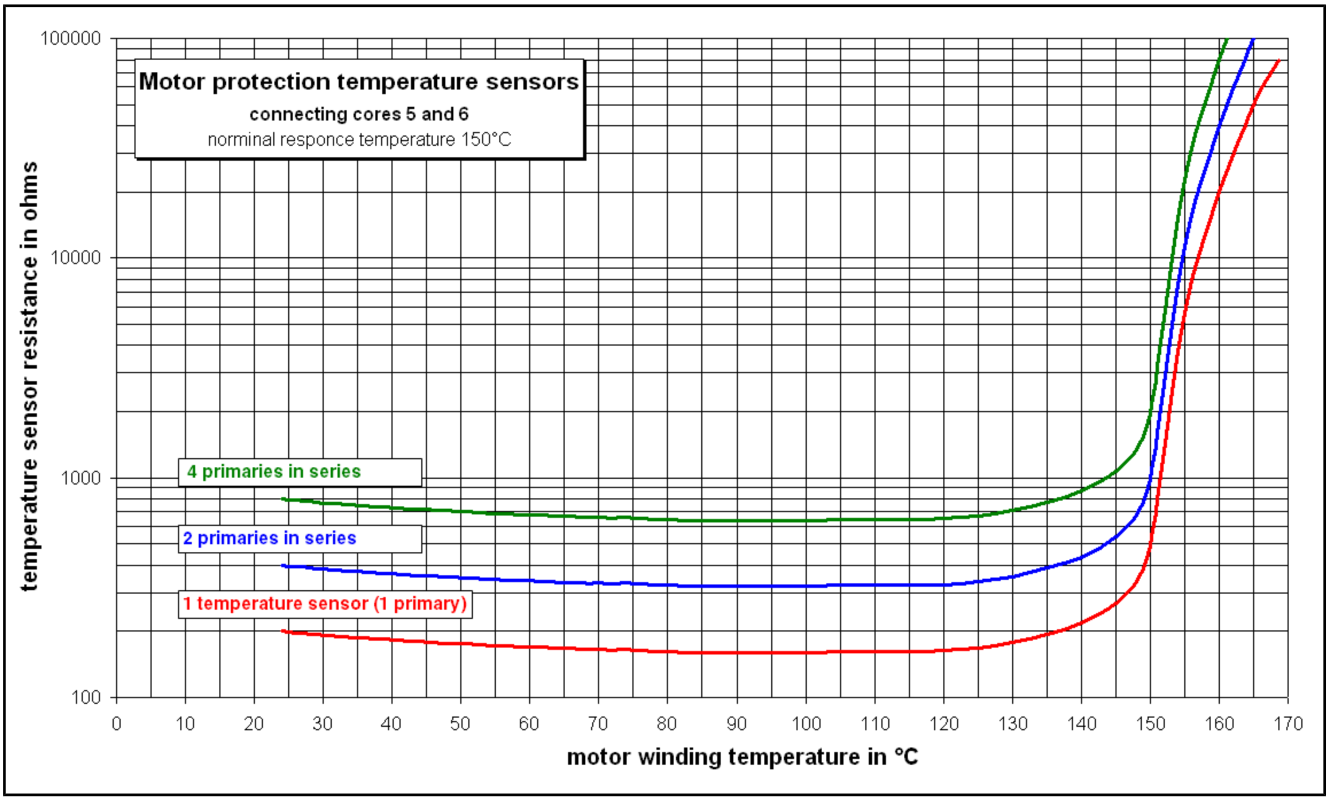



*Fig.9-65: Characteristik of temperature sensors motor protection (PTC)*

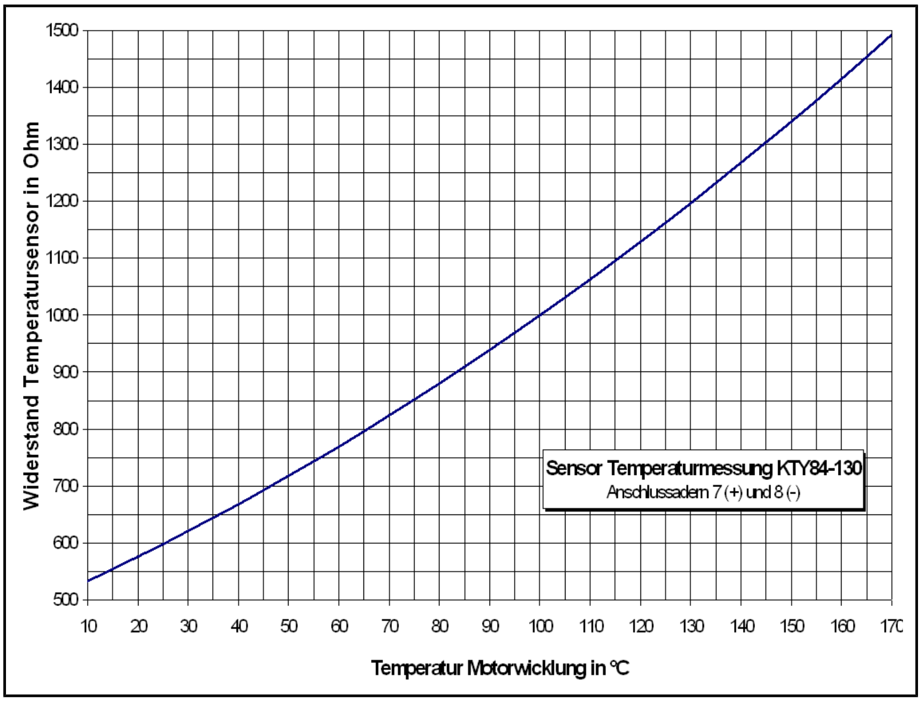



*Fig.9-66: Characteristic of temperature measurement sensor KTY84-130 (PTC)*

A polynomial of degree 3 is sufficient for describing the resistance characteristic of the sensor used for temperature measurement (KTY84-130). In the following, this is specified for determining a temperature from a given resistance and vice-versa.

**Temperature Depending on Resistance**

$$T_w = A \cdot R_{KTY}^{\ 3} + B \cdot R_{KTY}^{\ 2} + C \cdot R_{KTY} + D$$

| | |
|---|---|
| $T_w$ | Winding temperature of the motor in °C |
| $R_{KTY}$ | Resistance of the temperature sensor in Ohms |
| A | 3.039 ·10-8 |
| B | -1.44 ·10-4 |
| C | 0.358 |
| D | -143.78 |

*Fig.9-67: Polynomial used for determining the temperature with a known sensor resistance (KTY84)*

**Resistance Depending on Temperature**

$$R_{KTY} = A \cdot T_w^{\ 3} + B \cdot T_w^{\ 2} + C \cdot T_w + D$$

| | |
|---|---|
| $T_w$ | Winding temperature of the motor in °C |
| $R_{KTY}$ | Resistance of the temperature sensor in Ohms |
| A | 1.065 ·10-6 |
| B | 0.011 |
| C | 3.93 |
| D | 492.78 |

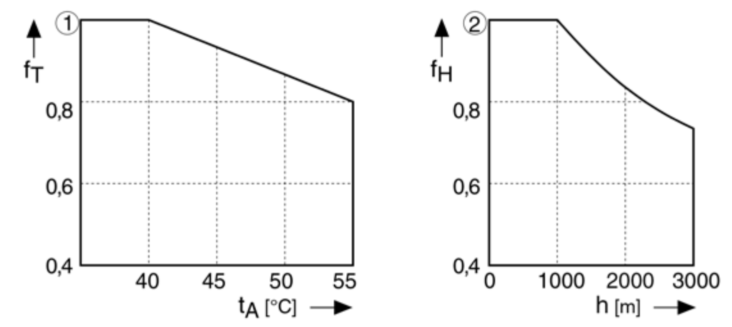
*Fig.9-68: Polynomial used for determining the sensor resistance (KTY84) with a known temperature*

## 9.8 Setup Elevation and Ambient Conditions

The performance data specified for the motors apply under the following conditions:

- Ambient temperatures +0 ... +40 °C
- Setup elevation of 0 m to 1,000 m above sea level.

Different conditions lead to a departing of the data according to the following diagrams. Do occur deviating ambient temperatures and higher setup elevations at the same time, both utilization factors must be multiplied.




| | |
|---|---|
| ① | Utilization depending on the ambient temperature |
| ② | Utilization depending on the setup elevation |
| $f_T$ | Temperature utilization factor |
| $t_A$ | Ambient temperature in degrees Celsius |
| $f_H$ | Height utilization factor |
| h | Setup elevation in meters |

*Fig.9-69: IndraDyn L utilization factors*

If **either** the ambient temperature **or** the setup height exceeds the nominal data:

1. Multiply the motor data provided in the selection data with the calculated utilization factor.
2. Ensure that the reduced torque data are not exceeded by your application.

If **both** the ambient temperature **and** the site altitude exceed the nominal data:

1. Multiply the load factors $f_T$ and $f_H$ determined.
2. Multiply the value obtained by the motor data specified in the selection data.

Ensure that your application does not exceed the reduced motor data.

The details for the utilization against the setup elevation and environmental temperature do not apply to the defined liquid coolant on the motor, but on the whole drive system, consisting of motor, drive controller and mains supply.

## 9.9 Protection Class

The design of the IndraDyn L synchronous linear motors complies with the following degrees of protection according to DIN VDE 0470, Part 1, ed. 11/1992 (EN 60 529):

| Motor components | Degree of protection |
|---|---|
| Primary part with standard encapsulation<br>Primary part with thermo encapsulation<br>Secondary part | IP 65 |

*Fig.9-70: Protection class of IndraDyn L motors*

The type of protection is defined by the identification symbol IP (International Protection) and two reference numbers specifying the degree of protection.

The **first digit** defines the degree of protection against contact and penetration of foreign particles. The **second digit** defines the degree of protection against water.

| 1st digit | Degree of protection |
|---|---|
| 6 | Protection against penetration of dust (dust-proof); complete contact protection |
| 2nd digit | Degree of protection |
| 5 | Protection against a water jet from a nozzle directed against the housing from all directions (jet water) |

*Fig.9-71: IP degrees of protection*

The tests for the second code number are done with fresh water. If cleaning is effected using high pressure and/or solvents, coolants, or penetrating oils, it might be necessary to select a higher degree of protection.

WARNING

**Personal injuries, damaging or destroying motor components!**

⇒ Use IndraDyn L synchronous linear motors only in environments for which the specified class of protection proves sufficient.

## 9.10 Compatibility Test

All Rexroth controls and drives are developed and tested according to the latest state-of-the-art of technology.

As it is impossible to follow the continuing development of all materials (e. g. lubricants in machine tools) which may interact with our controls and drives, it cannot be completely ruled out that any reactions with the materials used by Bosch Rexroth might occur.

For this reason, before using the respective material a compatibility test has to be carried out for new lubricants, cleaning agents etc. and our housings / our housing materials.

## 9.11 Magnetic Fields

The secondary parts of synchronous linear motors are equipped with permanent magnets, which are not magnetic shielded.

To be able to assess EMC problems (e.g. the influence on inductive switches or inductive measuring systems), chip attraction, and for personal protection, the values of the magnetic induction as a function of the distance to the secondary part are specified below.

The representation distinguishes between ferromagnetic materials (e.g. steel) and non-ferromagnetic materials (e.g. air), and between different directions.

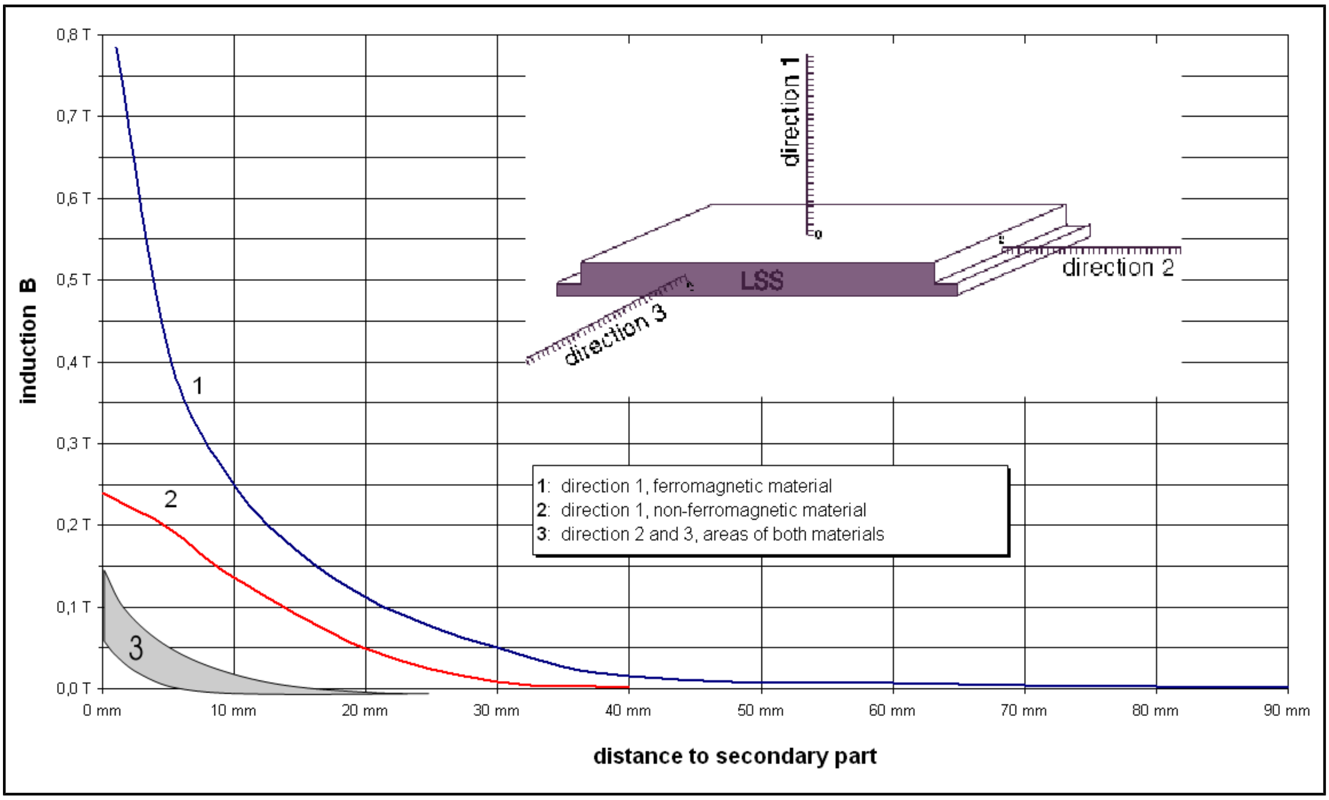



*Fig.9-72: Magnetic induction in ferromagnetic and non-ferromagnetic materials vs. the distance to the secondary part*

☞ Secondary parts of IndraDyn L motors generate a static magnetic field.

**Chip Attraction**

Ferromagnetic chips are not attracted at a distance of approximately 100 mm from the surface of the secondary part.

☞ It must be ensured that the secondary part is not located in the immediate chip area of the machine. Suitable covers must be provided.

# 9.12 Vibration and Shock

According to IEC 721-3-3 edition 1987 or EN 60721-3-3 edition 06/1994, IndraDyn L motors are approved for the utilization in areas that are exposed to vibration and/or shock as given in fig. 9-73 "Limit data for sinusoidal vibrations" on page 138 and fig. 9-74 "Limits for shock load" on page 138 IndraDyn L motors may be used in stationary weather-proof operation corresponding to **class 3M5**

| Influencing quantity | Unit | Maximum value |
|---|---|---|
| Amplitude of the excursion at 2 to 9 Hz | mm | 0,3 |
| Amplitude of the acceleration at 9 to 200 Hz | m/s² | 1 |

*Fig.9-73: Limit data for sinusoidal vibrations*

| Influencing quantity | Unit | Maximum value |
|---|---|---|
| Total shock-response spectrum (according to IEC721-1, Edition 1990; Table 1, Section 6) | | Type II |
| Reference acceleration, in IEC 721: Peak acceleration | m/s² | 250 |
| Duration | ms | 6 |

*Fig.9-74: Limits for shock load*

WARNING

**Motor damage and loss of warranty!**

⇒ A motor, used outside of specified operating conditions can be damaged. In addition, any warranty claim will expire.

⇒ Ensure that the maximum values specified in fig. 9-73 "Limit data for sinusoidal vibrations" on page 138 and fig. 9-74 "Limits for shock load" on page 138 for storage, transport, and operation of the motors are not exceeded.

# 9.13 Housing Surface

The following table shows the condition of the enclosure surface when delivered.

| Motor component | Housing surface | Note |
|---|---|---|
| Standard encapsulation primary part | Stainless steel V4A with black printing (RAL 9005) | Varnish resistant to weather, yellowing, chalking, thinned acids and thinned lyes |
| Thermal encapsulation primary part | Stainless steel V4A, front end aluminum, blank | |
| Secondary part segments | Cover plate stainless steel V4A, magnetic base carrier C45, chromatic | |

*Fig.9-75: Layout of enclosure surface*

It is possible to provide the surface of the motor components with additional varnish with a coat thickness no more than 40 µm. Check the adhesion and resistance of the paint coat before applying it.

# 9.14 Noise Emission

The noise emission of synchronous linear drives can be compared with conventional inverter-operated feed drives.

Experience has shown that the noise generation chiefly depends on

- the employed linear guides (velocity-related travel noise),
- the mechanical design (following cover, etc.), and
- the settings of drive and controller (e.g. switching frequency)

A generally valid specification is therefore not possible.

# 9.15 Length Measuring System

## 9.15.1 General Information

A linear scale is required for measuring the position and the velocity. Particularly high requirements are placed upon the linear scale and its mechanical connection. The linear scale serves for high-resolution position sensing and to determine the current speed.

☞ The necessary length measuring system is not in the scope of delivery of Bosch Rexroth and has to be provided and mounted from the machine manufacturer himself (fig. 9-81 "Recommended linear scales for linear motors" on page 143).

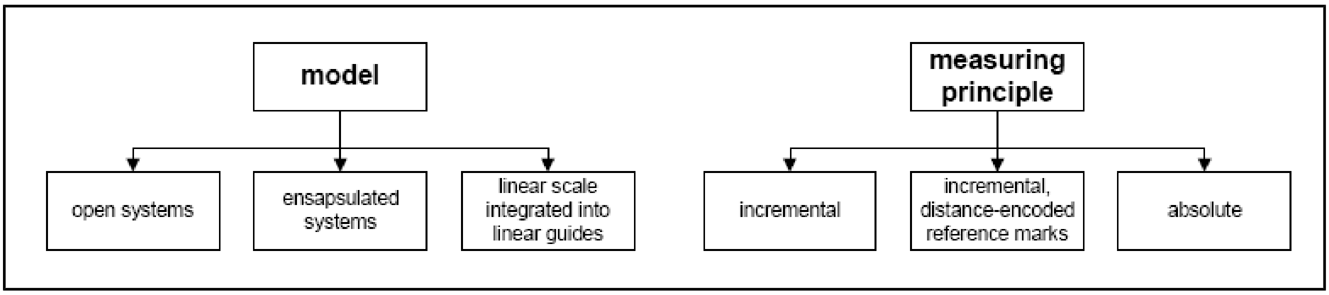



*Fig.9-76: Classification of linear scales*

**Particularities of Synchronous Linear Motors**

It is necessary at synchronous linear motors to receive the position of the primary part relating on the secondary part by return after start or after a malfunction (pole position recognition). Using an absolute linear scale is the optimum solution here.

## 9.15.2 Selection Criterias for Length Measuring System

### General Information

Depending on the operating conditions, open or encapsulated linear scales with different measuring principles and signal periods can be used. The selection of a suitable linear scales mainly depends on:

- the maximum feed rate (model, signal period)
- the maximum travel (measuring length, model)
- if applicable, utilization of coolant lubricants (model)
- produced dirt, chips etc. (model)
- the accuracy requirements (signal period)

## Frame Sizes

| Open model | Encapsulated model | Measuring system, integrated in rail guides |
|---|---|---|
| **Advantages:** | | |
| - High traverse rates<br>- High accuracy<br>- No friction | - Easy installation<br>- High protection class<br>- Incremental and absolute measurement available | - Combined guidance and measurement<br>- No additional installation required<br>- Highest protection class<br>- High traverse rates<br>- Little space required |
| **Disadvantage:** | | |
| - Low protection class<br>- More complicated mounting and adjustment<br>- Currently no absolute measurement systems available | - Maximum velocity currently 120m/min | - No absolute measurement systems available |

*Fig.9-77: Advantages and disadvantages of different linear scales models*

**Open Model**

If there are no dirt, chips, etc. in a machine or system and if coolant lubricants will never be used, employing an open linear scale is recommended. Thus open linear scale are frequently used for handling axes, precision and measuring machines, and in the semiconductor industry.

**Encapsulated Model**

Encapsulated systems should be employed if chips are produced and/or coolant lubricants are used. To achieve highest operational reliability, an encapsulated system can have additional sealing air. Encapsulated linear scales are chiefly used at chip-producing machine tools.

**Measuring System, integrated in Rail Guides**

The ball and roller rail guides from Rexroth are available with an integrated inductive linear scales. The system consists of a separate scanner (read head) and a material measure that is integrated into the rail. The material measure is accommodated in a groove of the guide rail, and is protected by a tightly welded stainless steel type. The read head is attached directly to the guide carriage.

The system is insensitive against soiling (e.g. dust, chips, coolant, etc.) and magnetic fields. Due to the little space required, the compact and robust device (measuring system and guides) permits simplified structures compared with an externally attached measuring system. There are no costs for material and installation of external systems.

## Measuring Principle

**Absolute Scales**

The advantages of an absolute linear scale result from the fact that a high availability and operational reliability of the axis of motion and, consequently, of the entire system is guaranteed.

**Advantage:**

- Monitoring and diagnosis functions of the electronic drive system are possible without any additional wiring
- No axis travel limit switches required
- The maximum available motor force is available at any point of the travel immediately after power-up.
- No referencing required
- Easy commissioning of horizontal and vertical axes
- pole position recognition only required for initial commissioning

**Disadvantage:**

- Maximum measuring length is limited (3040mm)
- Only encapsulated systems available

☞ An ENDAT interface is required if absolute linear scales are used.

Using an absolute linear scales makes it possible that the pole position recognition of the motor need only be performed once for iniial commissioning. This drive-internal procedure is possible without activating the power. This provides advantages when commissioning vertical axes, in particular.

Rexroth recommends the absolute linear scale LS181 and LC481 from Heidenhain. Both systems are equipped with an ENDAT interface.

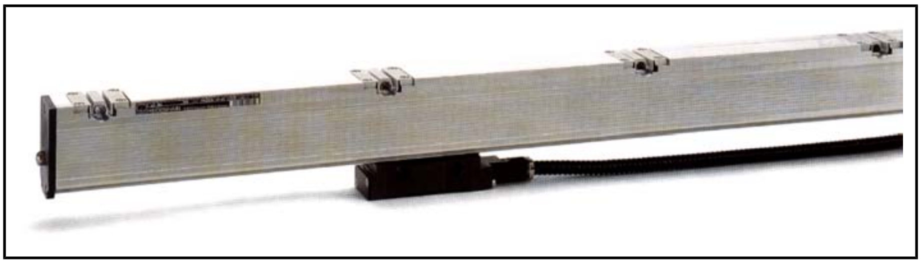


*Fig.9-78: Absolute encapsulated length measuring system LC181*

**Incremental Scales**

When an incremental linear scale is used together with a synchronous linear motor, the pole position must be measured upon each power-up. This is done, using a drive-internal procedure that must be executed whenever the axis is switched on. After this, a force processing of the motor is possible.

☞ With incremental linear scales, the drive-internal pole position recognition procedure must be executed upon each power-up. Pole position recognition required the primary part to be moved!

**Advantage:**

- Depending on the model, travels up to 30 m (or unlimited distance) possible
- High feed rate possible
- Different signal periods and, consequently, different position resolutions possible.

**Disadvantage:**

- Pole position must be measured upon each power-up.
- Pole position recognition required the primary part to be moved
- Pole position recognition is not possible for vertical axes
- Pole position recognition is not possible for securely braked axes or for axes at the hard stop
- Pole position recognition of Gantry axes may cause problems
- Reference point interpretation and homing switch are required
- Safety limit switch is required

**Incremental Linear Scales with distance-encoded Reference Marks**

Incremental linear scales with distance-encoded reference marks offer the benefit of a simplified and, even more important, shortened referencing. With such a system, referencing requires the axis merely to be moved by several centimeters (depends on the model).

☞ Distance-encoded scales do not perform absolute measurement. Pole position recognition must also be performed upon each power-up (like incremental systems that are not distance encoded).

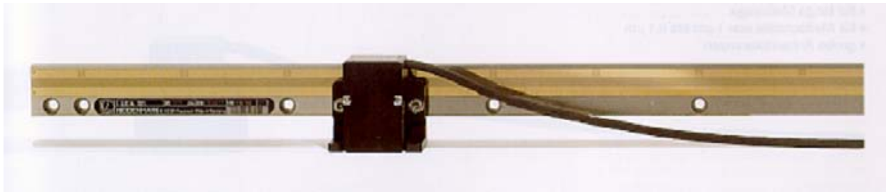


*Fig.9-79: Open incremental linear scales LIDA185C with distance-encoded reference marks*

## Maximum Permitted Velocity and Acceleration

**Maximum permissible feed rate**

One limitation factor of the maximum permissible feed rate of a length measuring system are the sealing lips and the guides of the scan carriage on the glass rule. Currently, the velocity of an encapsulated system is limited to 120 m/min.

The other limitation factor of the maximum permissible feed rate is the frequency limit of the output signals (manufacturer´s specifications) or the maximum permissible input frequency of subsequent circuits (drive controller).

$$v_{max} = f_{max} \cdot \text{Signal period} \cdot 60$$

| | |
|---|---|
| $v_{max}$ | Maximum feed rate in m/min |
| Signal period | Signal period of linear scale in mm |
| $f_{max}$ | Maximum input frequency of scale interface (DAG 1 VSS: 500kHz) (DLF 1 VSS: 500kHz) |

*Fig.9-80: Maximum traverse rate of linear scale related to the maximum input frequency of the scale interface*

**Maximum Permissible Acceleration in the Measuring Direction**

The very rigid internal structure of open linear scales permits maximum acceleration values in the measuring direction of up to 200 m/s². To permit relatively high attachment tolerances, the scan carriage of encapsulated linear scales cannot rigidly be connected with the mounting foot. Encapsulated linear scales systems for linear motors, however, are comparatively rigid and may be used for maximum accelerations in the measuring direction between 50 m/s² and 100 m/s² (depending on the length measuring system employed).

☞ Please refer to the documents from the corresponding manufacturer for detailed and updated information.

## Position Resolution and Position Accuracy

To reach a high resolution of the linear scale, an interpolation of the sinusoidal input signal of the linear scale is performed in the drive controller. Depending on the maximum travel range and on the signal period, a drive-internal position resolution of less than 1 mm is possible.

☞ The drive-internal position resolution does not correspond to the positioning accuracy! The absolute positioning accuracy is depending on the entire drive system, including mechanical systems.

## Measuring System Cables

Ready-made cables of Rexroth are available for the electrical connection between the output of the linear scale and the input of the scale interface. To ensure maximum transmission and scale interference safety, you should preferably use these ready-made cables.

## Recommended linear scales for linear motors

| Manufacturer Type | Signal period in mm (S-0-0116) | Model | Output signals | Measuring principle | Maximum measuring length in mm | Maximum velocity in m/min | P-0-0074 | Reference marks |
|---|---|---|---|---|---|---|---|---|
| Heidenhain LC 181 | 0.016 | Encapsulated | Sinus 1Vss | Absolute ENDAT | 3,040 | 120 | 8 | none (Absolute) |
| Heidenhain LC 481 | 0.02 | Encapsulated | Sinus 1Vss | Absolute ENDAT | 2,040 | 120 | 8 | none (Absolute) |
| Heidenhain LS 486 | 0.02 | Encapsulated | Sinus 1Vss | Incremental | 2,040 | 120 | 2 | one (Middle measuring length) |
| Heidenhain LS 486C | 0.02 | Encapsulated | Sinus 1Vss | Incremental | 2,040 | 120 | 2 | Distance-coded |
| Heidenhain LS 186 | 0.02 | Encapsulated | Sinus 1Vss | Incremental | 3,040 | 120 | 2 | one (Middle measuring length) |
| Heidenhain LS 186C | 0.02 | Encapsulated | Sinus 1Vss | Incremental | 3,040 | 120 | 2 | Distance-coded |
| Heidenhain LB 382 | 0.04 | Encapsulated | Sinus 1Vss | Incremental | 30,040 | 120 | 2 | Selectable by blinds |
| Heidenhain LB 382C | 0.04 | Encapsulated | Sinus 1Vss | Incremental | 30,040 | 120 | 2 | Distance-coded |
| Heidenhain LF 183 | 0.004 | Encapsulated | Sinus 1Vss | Incremental | 3,040 | 60 | 2 | Selectable by magnets |
| Heidenhain LF 183C | 0.004 | Encapsulated | Sinus 1Vss | Incremental | 3,040 | 60 | 2 | Distance-coded |
| Heidenhain LF 481 | 0.004 | Encapsulated | Sinus 1Vss | Incremental | 1,220 | 60 | 2 | one (Middle measuring length) |
| Heidenhain LF 481C | 0.004 | Encapsulated | Sinus 1Vss | Incremental | 1,220 | 60 | 2 | Distance-coded |
| Heidenhain LIDA 185 | 0.04 | Open | Sinus 1Vss | Incremental | 30,040 | 480 | 2 | Selectable by magnets |
| Heidenhain LIDA 185C | 0.04 | Open | Sinus 1Vss | Incremental | 30,040 | 480 | 2 | Distance-coded |
| Heidenhain LIDA 187 | 0.04 | Open | Sinus 1Vss | Incremental | 6,040 | 480 | 2 | Selectable by magnets |
| Heidenhain LIDA 187C | 0.04 | Open | Sinus 1Vss | Incremental | 6,040 | 480 | 2 | Distance-coded |
| Renishaw RGH22 | 0.02 | Open | Sinus 1Vss | Incremental | 50,000 | 500 | 2 | Selectable by magnets |

| Manufacturer Type | Signal period in mm (S-0-0116) | Model | Output signals | Measuring principle | Maximum measuring length in mm | Maximum velocity in m/min | P-0-0074 | Reference marks |
|---|---|---|---|---|---|---|---|---|
| Renishaw RGH24 | 0.02 | Open | Sinus 1Vss | Incremental | 50,000 | 500 | 2 | Selectable by magnets |
| Renishaw RGH25 | 0.02 | Open | Sinus 1Vss | Incremental | 50,000 | 500 | 2 | Selectable by magnets |
| Renishaw RGH41 | 0.04 | Open | Sinus 1Vss | Incremental | 50,000 | 640 | 2 | Selectable by magnets |
| Heidenhain LIF 181R | 0.004 | Open | Sinus 1Vss | Incremental | 3,040 | 120 | 2 | one (Middle measuring length) |
| Heidenhain LIF 181C | 0.004 | Open | Sinus 1Vss | Incremental | 3,040 | 120 | 2 | Distance-coded |
| Heidenhain LIP 481R | 0.002 | Open | Sinus 1Vss | Incremental | 420 | 60 | 2 | one (Middle measuring length) |
| Rexroth integrated measuring system | 1.000 | integrated into slide mounting | Sinus 1Vss | Incremental | 4,000 | 600 | 2 | Single reference or Distance-coded |

P-0-0074 Drive parameter ”Encoder type 1”
S-0-0116 Drive parameter ”Encoder 1 resolution”
*Fig.9-81: Recommended linear scales for linear motors*

- To ensure maximum interference immunity, Rexroth recommends the voltage interface with 1 $V_{SS}$.
- Please refer to the documents from the corresponding manufacturer for detailed and possibly updated information.

## 9.15.3 Mounting the Length Measuring Systems

**Elasticity of the Coupling to the Machine**

With linear drives, the mounting of the measuring system to the machine can limit the bandwidth of the position control loop. As a consequence for the design, this means that the coupling between the scan unit and the rule of an open linear scale, or between the rule enclosure of an encapsulated linear scale, and the machine – with respect to the natural frequency – must be significantly higher than the one of the linear scale. The natural frequencies of today´s encapsulated linear scales are 2 kHz and higher.

It must also be ensured that the linear scales is not attached to vibrating machine components. In particular, attaching the system in the vicinity of vibration maximal must be avoided.

**Mounting Method**

In order to minimize the moved masses and to obtain the highest rigidity in the measuring direction, the scanner unit should always be moved if possible.

**Open Linear Scales Systems**

The user should provide an encapsulation if an open linear scale is employed despite adverse conditions (chips, dust, etc.). It must also be noted that the scanning head must be adjusted when the open linear scale is installed. Corresponding adjustment possibilities must be provided in the design (please heed the specifications of the manufacturer).

**Encapsulated Linear Scales Systems**

To obtain relatively high installation tolerances, the scan carriage of encapsulated linear scale is connected with the mounting base via coupling that is very rigid in the measuring direction and slightly flexible perpendicularly to the measuring direction. If the rigidity of this coupling in the measuring direction is too weak, there are low natural frequencies in the feedback of the position and velocity control loop that can limit the bandwidth. The encapsulated linear scales that are recommended for linear motors usually possess a natural frequency in the measuring direction that is above 2 kHz. Thus, the natural frequency of the linear scale in the measuring direction can be neglected with respect to the mechanical natural frequencies of the machine.

**Parallel Arrangement of Motors with one Linear Scale System**

If several motors on an axis are used with a single linear scale, the motors should be positioned as symmetrically as possible.

**Gantry axes**

With a Gantry axis, where each motor of pair of motors is assigned to a linear scale system, the distance between motor and linear scale should be as small as possible. The accuracy of the linear scale as such and with respect to each other should be less than 5 µm/m. Drive-internal axis error compensations can minimize remaining misalignments between the linear scales.

## 9.16 Linear Guides

Depending on the motor arrangement, the attractive, feed and process forces and the velocities of more than 600 m/min that can be reached today stress the linear guides. The employed linear guides must the able to handle

- Attractive force between primary and secondary part and
- Machining and acceleration forces

Depending on the application, the following linear guides are employed:

- Ball or roll rail guides
- Slideways
- Hydrostatic guides
- Aerostatic guides

The following requirements should be taken into account when a suitable linear guide system is selected:

- High accuracy and no backlash
- Low friction and no stick-slip effect
- High rigidity
- Steady run, even at high velocities
- Easy mounting and adjustment

## 9.17 Braking Systems and Holding Devices

The following systems can be used as braking systems and/or holding devices for linear motors:

- External braking devices
- Clamping elements for linear guides
- Holding brakes integrated in the weight compensation

See also chapter 15.1 "Recommended Suppliers of Additional Components " on page 247.

☞ Further designs about stand-still of linear motors are given in chapter 9.18 "End Position Shock Absorber " on page 146 and chapter 9.22 "Deactivation upon EMERGENCY STOPand in the Event of a Malfunction " on page 149 as well as in the appropriate functional description of the drive controller.

## 9.18 End Position Shock Absorber

Where linear drives with frequently high traverse rates and accelerations are concerned, uncontrolled movements (such as coasting after a mains failure) cannot be definitely avoided.

Suitable energy-absorbing end position shock absorber must be provided in order to protect the machine during uncontrolled coasting of an axis.

WARNING

**Damage on machine or motor components when driving against hard stop!**

⇒ Use suitable energy-absorbing end position shock absorber

⇒ Adhere to the specified maximum decelerations

☞ The necessary spring excursion of the shock absorbers must be taken into account when the end position shock absorber are integrated into the machine (in particular when the total travel path is determined).

**Maximum Deceleration when Driving against End Stop**

Given by the type of fastening and by the type of the primary part (quantity of the fastening screws, attractive force, mass, etc.), there is a maximum deceleration in the movement onto an end stop. If this maximum deceleration is exceeded, this can lead to loosening the primary part and to damaging of motor components.

The maximum permissible deceleration upon moving against end stop is 300 m/s².

☞ Using a suitable end stop shock absorber, the maximum permissible deceleration for moving against an end stop must be limited to **300 m/s²**.

**Braking Distance to be kept when Driving against End Stop**

With the known maximum deceleration of 300 m/s² and the maximum possible velocity, the minimum spring excursion can be calculated as follwos:

$$s_{min} = \frac{v_{max}^2}{2158}$$

$s_{min}$ Minimum braking distance in mm

$v_{max}$ Maximum possible velocity in m/min

*Fig.9-82: Braking distance to be kept when driving against end stop*

## 9.19 Axis Cover Systems

Depending on the application, design, operational principle and features of synchronous linear motors the following requirements on axis cover systems apply:

- High dynamic properties (no overshoot, little masses)
- Accuracy and smooth run

- Protection of motor components against chips, dust and contamination (in particular ferromagnetic parts),
- Resistance to oil and coolant lubricants
- Robustness and wear resistance

The following axis cover systems can be used:

- Bellow covers
- Telescopic covers
- Roller covers

A suitable axis cover system should be configured, if possible, during the early development process of the machine or system – supportet by the corresponding specialized supplier (see chapter 15.1 "Recommended Suppliers of Additional Components " on page 247).

## 9.20 Wipers

It is generally possible, to use a wiper for removing chips directly on the secondary part, if the measures to protect the motor installation space or to protect the air gap between primary and secondary part cannot be optimally implemented (see chapter 9.3.4 "Protection of the Motor Installation Space" on page 103).

A significant disadvantage of this measure is, however, if magnet dirt (chips, swarf, etc.) exists on the secondary part, this is difficult to remove and is afflicted with a high rate of wear because of the powerful attractive forces of the secondary part For this reason, the wiper and the motor components should be checked in short intervals onto wear or damage.

The following points must be taken into account when a suitable wiper system is selected and used:

**Secondary Part Segments**

If possible, a wiper should be used only on whole secondary part segments. If more than one secondary part segment is used, joints between the secondary part segment must be taken into account (destruction of the wiper or of the secondary parts). In these cases, a defined distance – smaller than the air gap among primary and secondary part – between wiper and secondary part or a wiper in the form of a hard brush can help.

---

☞ Does the secondary part exists of several aligned secondary parts and can come residues, coolant lubricant, grease, etc. into the installation space of the motor during operation, please note the following:

⇒ The wiper wores with subject to technical reasons. Dirt, residues, etc. will not be reliably removed with increasing wear.

⇒ Check the pollution degree of the secondary part and the condition of the wiper in regular and specified intervals . Hereby, remove already created residues onto the surface of the secondary part.

---

**Ferromagnetic Chips**

The secondary part attracts ferromagnetic chips at a distance of approx. 100 mm. These attractive forces must be taken into account when ferromagnetic chips are removed.

**Temperature produced by Friction**

If the utilization of the wiper causes a significant rise of the temperature on the secondary part surface, it must be ensured that this temperature does not exceed the limit of 70 °C.

**Mounting the Wiper**

The wiper should be mounted to the superordinated machine construction. Mounting the wiper in additional holes directly on the primary part is not permitted.

**WARNING**

**Damage or destruction of motor components by inappropriate utilization of a wiper on the secondary part!**

- If possible, utilization only on whole secondary part segments
- Take slightly height differences of the secondary part segments into account
- Take temperature rises due to friction into account
- Observe possible surface damage due to friction.
- Mounting the wiper in additional holes directly on the primary part is not permitted

# 9.21 Drive and Control of IndraDyn L motors

## 9.21.1 General Information

The following figures shows a complete linear direct drive, consisting of a synchronous linear motor, length scale system, drive controller and superordinate control.

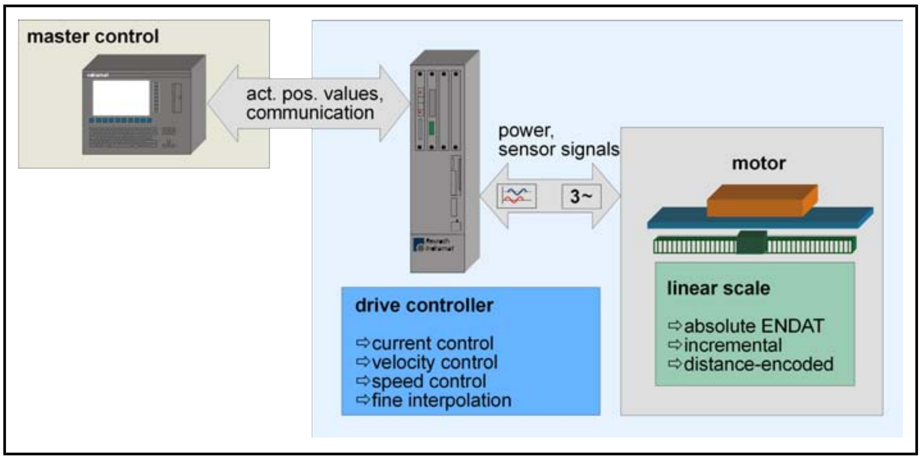



*Fig.9-83: Linear direct drive*

## 9.21.2 Drive Controller and Power Supply Modules

To control IndraDyn L motors, different digital drive controllers and power supply modules are available. These drive systems are configurable and of a modular or compact structure.

☞ The drive controllers and the related firmware for the IndraDyn L motors are the same as for the rotary drives from Bosch Rexroth.

## 9.21.3 Control Systems

A master control is required for generating defined movements. Depending on the functionality of the whole machine and the used control systems, Bosch Rexroth offers different control systems.

# 9.22 Deactivation upon EMERGENCY STOPand in the Event of a Malfunction

## 9.22.1 General Information

The deactivation of an axis, equipped with an IndraDyn L motor, can be initiated by

- EMERGENCY STOP,
- drive fault (e.g. response of the encoder monitoring function) or
- mains failure

For the options of deactivation an IndraDyn L motor in the event of a malfunction, distinction must be made between

- Deactivation by the drive,
- Deactivation by a master control and
- Deactivation by a mechanical braking device.

## 9.22.2 Deactivation by the Drive

As long as there is no fault or malfunction in the drive system, shutdown by the drive is possible. The shutdown possibilities depend on the occurred drive error and on the selected error response of the drive. Certain faults (interface faults or fatal faults) lead to a force disconnection of the drive.

WARNING

**Death, serious injuries or damage to equipment may result from an uncontrolled coasting of a switched-off linear drive!**

⇒ Construction and design according to the safety standards

⇒ Protection of people by suitable barriers and enclosures

⇒ Use external mechanical braking facilities

⇒ Use suitable energy-absorbing end position shock absorber

The parameter values of the drive response to interface faults and non-fatal faults can be selected. The drive switches off at the end of each fault response.

The following fault responses can be selected:

0 – Setting velocity command value to zero

Setting force command value to zero

Setting velocity command value to zero with command value ramp and filter

3 - Retraction

☞ Please refer to the corresponding firmware function description for additional information about the reaction to faults and the related parameter value assignments.

## 9.22.3 Deactivation by a Master Control

### Deactivation by control functions

Deactivation by the master control should be performed in the following steps:

1. The machine PLC or the machine I/O level reports the fault to the CNC control
2. The CNC control deactivate the drives via a ramp in the fastest possible way

3. The CNC control causes the power at the power supply module to be shut down.

**Drive initiated by the control shutdown**

Deactivation by the master control should be performed in the following steps:

1. The machine I/O level reports the fault to the CNC control and SPS
2. The CNC control or the PLC resets the controller enabling signal of the drives. If SERCOS interface is used, it deactivates the "E-STOP" input at the SERCOS interface module.
3. The drive responds with the selected error response.
4. The power at the power supply module must be switched off 500 ms after the controller enabling signal has been reset or the "E-STOP" input has been deactivated.

☞ The delayed power shutdown ensures the safe shutdown of the drive by the drive controller. With an undelayed power shutdown, the drive coasts in an uncontrolled way once the DC bus energy has been used up.

## 9.22.4 Deactivation via Mechanical Braking Device

Shutdown by mechanical braking devices should be activated simultaneously with switching off the power at the power supply module. Integration into the holding brake control of the drive controllers is possible, too. The following must be observed:

- Braking devices with electrical 24V DC control (electrically un-locking) and currents < 2 A can directly be triggered.
- Braking devices with electrical 24V DC control and currents > 2 A can be triggered via a suitable contractor.

Once the controller enabling signal has been removed, the holding brake control has the following effect:

- Fault reaction "0", "1" and "3".

  The holding brake control drops to 0 V once the velocity is less than 10 mm/min or a time of 400 ms has elapsed.
- Fault reaction "2":

  The holding brake control drops to 0 V immediately after the drive enabling signal has been removed.

## 9.22.5 Response to a Mains Failure

In order to be able to shut down the linear drive as fast as possible in the event of a mains failure,

- either an uninterruptible power supply or
- additional DC bus capacities (condensers), and /or
- mechanical braking facilities

must be provided.

**Determining the Required Additional DC Bus Capacitor**

Additional capacities in the DC bus represent an additional energy store that can supply the brake energy required in the event of a mains failure.

☞ The control voltage must be available even at a power failure for the time of braking! If needed, buffer the control voltage supply or feed the control voltage from the DC intermediate circuit if possible!

The additional capacity required for a deactivation upon a mains failure can be determined as follows:

$$C_{add} = \frac{m \cdot v_{max}}{U_{DCmax}^2 - U_{DCmin}^2} \cdot \left[ 3{,}5 \cdot \frac{F_{max}}{k_{iF}^2} \cdot R_{12} - v_{max} \cdot \left( \frac{F_R}{F_{max}} + 0.3 \right) \right]$$

| | |
|---|---|
| $C_{add}$ | Required additional DC bus capacitor in mF |
| m | Moved mass in kg |
| $v_{max}$ | Maximum velocity in m/s |
| $U_{DCmax}$ | Maximum DC bus voltage in V |
| $U_{DCmin}$ | Minimum DC bus voltage in V |
| $F_{max}$ | Maximum braking force of the motor in N |
| $k_{iF}$ | Motor constant (force constant) in N/A |
| $R_{12}$ | Winding resistance at 20°C |
| $F_R$ | Frictional force in N |

*Fig.9-84: Determining the required additional DC bus capacitor*

**Prerequisites:**

- Final velocity = 0
- Velocity-independent friction
- Constant deceleration
- Winding temperature 135 °C

☞ The maximum possible DC bus capacity of the employed power supply module must be taken into account when additional capacities are used in the DC bus. Do not initiate a DC voltage short-circuit when additional capacitors are employed.

### 9.22.6 Short-Circuit of DC Bus

Most of the power supply modules of Bosch Rexroth permit the DC bus to be shortened when the power is switched off, which also establishes a short-circuit between the motor phases. When the motor moves, this causes a braking effect according to the principle of the induction; thereby the motor phases are shorted. The reachable braking force is not very high and velocity-dependend. The DC bus short-circuit can therefore only be used to support existing mechanical braking devices.

## 9.23 Maximum Acceleration Changes (Jerk Limitation)

**Rate of current and force rise**

The maximum rate of current and force rise is determined by the available DC bus voltage and the motor inductance. As shown in fig. 9-85 "Maximum rate of current and force rise" on page 152, with highly dynamic movements and short strokes, the motor inductance should be low and the DC bus voltage as high as possible.

$$\frac{di}{dt} = \frac{U_{DC}}{L_{12}}$$

$$\frac{dF}{dt} = \frac{U_{DC}}{L_{12}} \cdot k_{iF}$$

| | |
|---|---|
| $U_{DC}$ | DC bus voltage in V |
| $L_{12}$ | Winding inductance in H |
| $k_{iF}$ | Motor constant (force constant) in N/A |
| $i$ | Current in A |
| $t$ | Time in s |

*Fig.9-85: Maximum rate of current and force rise*

The acceleration change per time unit (derivative of the acceleration) is known as jerk (fig. 9-88 "Maximum jerk (acceleration change)" on page 153).

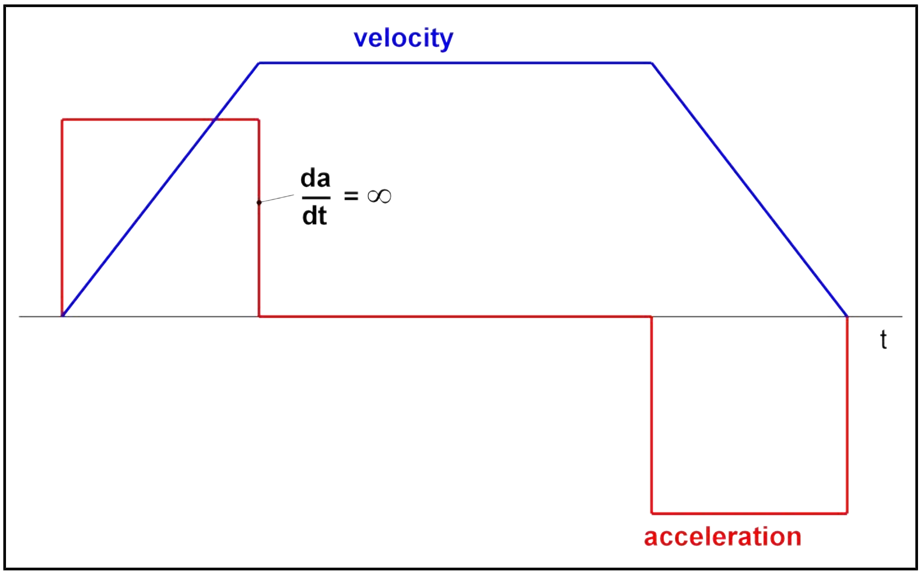



*Fig.9-86: Acceleration and velocity without jerk limitation*

☞ The drive controller or the master control must delimit the maximum jerk when direct drives are employed (acceleration ramp with da/dt ≠ ∞, fig. 9-87 "Acceleration and velocity with jerk limitation" on page 153).

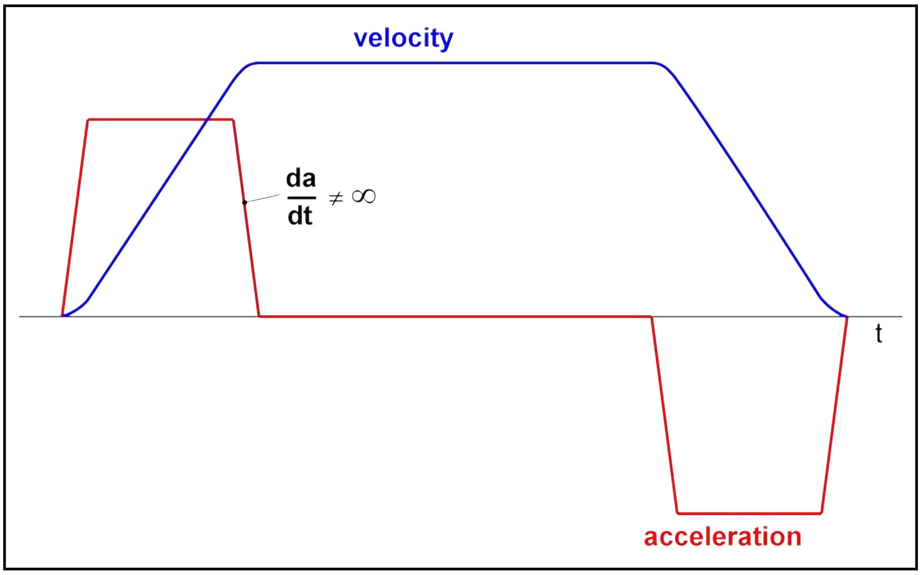



*Fig.9-87: Acceleration and velocity with jerk limitation*

**Maximum Jerk**

The maximum jerk is determined by the maximum rate of current rise, by the moved mass and by the motor constant:

$$r_{max} = \frac{da}{dt} = \frac{U_{DC} \cdot k_{iF}}{L_{12} \cdot m}$$

| | |
|---|---|
| m | Moved mass in kg |
| $U_{DC}$ | DC bus voltage in V |
| $k_{iF}$ | Motor constant (force constant) in N/A |
| $L_{12}$ | Winding inductance in H |
| a | Acceleration in m/s² |
| t | Time in s |

*Fig.9-88: Maximum jerk (acceleration change)*

# 9.24 Position and Velocity Resolution

## 9.24.1 Drive Internal Position Resolution and Position Accuracy

In linear direct drives, a linear scale is used for measuring the position. The linear scale for linear motors supply sinusoidal output signals. The length of such a sine signal is known as the signal period. It is mainly specified in mm or µm.

With the drive controllers from Bosch Rexroth, the sine signals are amplified again in the drive (see fig. 9-90 "Drive-internal multiplication and/or interpolation of the measuring system signals" on page 154). The drive-internal amplification also depends on the maximum travel area and the signal period of the length measuring system. It always employs $2^n$ vertices (e.g. 2048 or 4096).

Application and Construction Instructions

$$f_{int} = 2^{31} \cdot \frac{s_p}{x_{max}} \qquad \text{rounding to } 2^n$$

| | |
|---|---|
| $f_{int}$ | Multiplication factor (S-0-0256, Multiplication 1) |
| $s_p$ | Linear scale system signal period in mm (S-0-0116 resolution of encoder 1) |
| $x_{max}$ | Maximum travel (S-0-0278, maximum travel) |

*Fig.9-89: Multiplication factor*

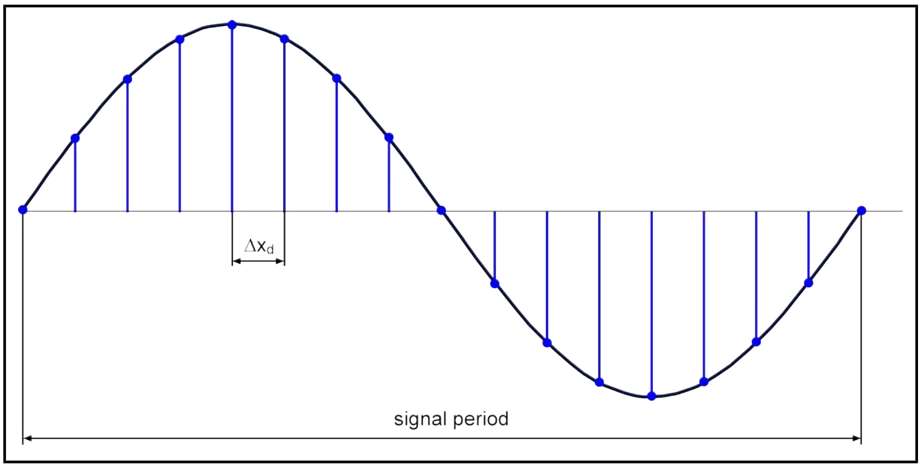



*Fig.9-90: Drive-internal multiplication and/or interpolation of the measuring system signals*

With a known signal period and a drive-internal multiplication, the drive-internal position resolution results as:

$$\Delta x_d = \frac{s_p}{f_{int}}$$

| | |
|---|---|
| $\Delta x_d$ | Drive-internal position resolution |
| $s_p$ | Linear scale system signal period (S-0-0116 resolution of encoder 1) |
| $f_{int}$ | Multiplication factor (S-0-0256, Multiplication 1) |

*Fig.9-91: Drive-internal position resolution*

☞ The drive-internal position resolution is not identical to the reachable positioning accuracy.

**Reachable Positioning Accuracy**

The reachable position accuracy depends on the mechanical and control-engineering total system and is not identical to the drive-internal position resolution.

The reachable position accuracy can be estimated as follows (using empirical values):

$$\Delta x_{abs} = \Delta x_d \cdot 30...50$$

| | |
|---|---|
| $\Delta x_d$ | Drive-internal position resolution |
| $\Delta x_{abs}$ | Position accuracy |

*Fig.9-92: Estimating the reachable position accuracy*

**Prerequisites:** Optimum controller setting

☞ The expected position accuracy cannot be better than the smallest position command increment of the superordinate control.

### 9.24.2 Velocity Resolution

The resolution of the velocity (velocity quantization) is proportional to the position resolution (see Fig. 9-88) and inversely proportional to the sample time $t_{AD}$ from:

$$\Delta v_d = \frac{\Delta x_d}{t_{AD}}$$

| | |
|---|---|
| $\Delta v_d$ | Velocity resolution in m/s |
| $\Delta x_d$ | Drive-internal position resolution |
| $t_{AD}$ | Sample time in s (DIAX04: 250µs, ECODRIVE03: 500µs, IndraDrive: Standard Performance 250µs / High Performance 125µs) |

*Fig.9-93: Velocity resolution*

## 9.25 Load Rigidity

### 9.25.1 General Information

The elastic deformability resistance of a structure against an external force is known as rigidity (usually specified in N/µm). The reciprocal value of the rigidity is known as elasticity.

Influence of disturbing factors on a controlled electric drive is called load rigidity. It is distinguished between **static** and **dynamic** load rigidity.

### 9.25.2 Static Load Rigidity

The static load rigidity of a linear direct drive only depends on the maximum motor force and the drive-internal position resolution:

$$c_{stat} = \frac{F_{max}}{\Delta x_D}$$

| | |
|---|---|
| $c_{stat}$ | Static load rigidity in N/µm |
| $F_{max}$ | Maximum force of the motor in N |
| $\Delta x_D$ | Drive-internal position resolution in µm |

*Fig.9-94: Static load rigidity of linear direct drives*

☞ The rigidity of the machine structure must be taken into account when the static load rigidity of a linear direct drive is rated.

$$d_{stat} = \frac{\Delta x_D}{F_{max}}$$

| | |
|---|---|
| $d_{stat}$ | Static elasticity in N/µm |
| $F_{max}$ | Maximum force of the motor in N |
| $\Delta x_D$ | Drive-internal position resolution in µm |

*Fig.9-95: Static elasticity of linear direct drives*

## 9.25.3 Dynamic Load Rigidity

Dynamic load rigidity and elasticity are frequency-dependent variables. The dynamic load rigidity of a linear direct drive only depends on the controller settings (current, velocity and position controller) and on the moved masses (fig. 9-97 "Estimating the dynamic load rigidity" on page 157). The maximum elasticity (or the minimum rigidity) is in the area of the natural frequency of the control loop.

In a simplified form, the following figure shows a typical elasticity frequency response.

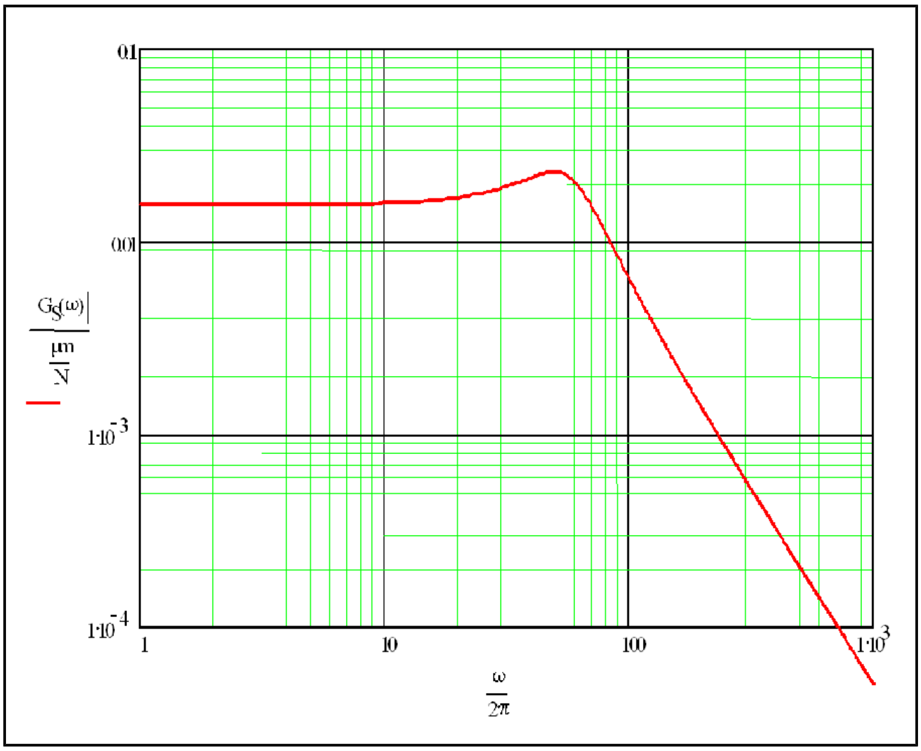



*Fig.9-96: Example elasticity frequency response of a linear direct drive*

**Estimating the Dynamic Load Rigidity**

Despite the frequency sensitivity, a sufficiently exact estimate of the dynamic rigidity can be made for the area below the natural frequency of the control loop:

$$c_{dyn} = \frac{0.06 \cdot k_p \cdot k_{iF} \cdot (1 + 0.0167 \cdot k_v \cdot T_n)}{T_n \cdot \left(1 + \frac{e^{-D \cdot \frac{\pi}{\sqrt{1-D^2}}}}{\sqrt{1-D^2}}\right)}$$

mit / with

$$D = \frac{1}{2} \cdot \sqrt{\frac{0.06 \cdot k_p \cdot k_{iF} \cdot T_n}{m \cdot (1 + 0.0167 \cdot k_v \cdot T_n)}}$$

| | |
|---|---|
| $c_{dyn}$ | Dynamic load rigidity in N/µm |
| D | Attenuation |
| $k_{iF}$ | Motor constant (force constant) in N/A |
| $k_p$ | Proportional gain of velocity controller in A·min/m |
| $k_v$ | Proportional gain of position controller (Kv-factor) in m/min·mm |
| $T_n$ | Integral time of velocity controller in ms |
| m | Moved mass in kg |

*Fig.9-97: Estimating the dynamic load rigidity*

$$d_{dyn} = \frac{1}{c_{dyn}}$$

| | |
|---|---|
| $c_{dyn}$ | Dynamic load rigidity in N/µm |
| $d_{dyn}$ | Dynamic elasticity in N/µm |

*Fig.9-98: Determining of the dynamic elasticity*

$$\omega_0 = \frac{1}{2 \cdot \pi} \cdot \sqrt{\frac{1000 \cdot k_p \cdot k_{iF} \cdot (60 + k_v \cdot T_n)}{m \cdot T_n}}$$

| | |
|---|---|
| $\omega_0$ | Natural frequency in Hz |
| $k_{iF}$ | Motor constant (force constant) in N/A |
| $k_p$ | Proportional gain of velocity controller in A·min/m |
| $k_v$ | Proportional gain of position controller (Kv-factor) in m/min·mm |
| $T_n$ | Integral time of velocity controller in ms |
| m | Moved mass in kg |

*Fig.9-99: Determining the controller´s natural frequency*

# 10 Motor-Controller-Combinations

## 10.1 General Explanation

### 10.1.1 General Information

This chapter contains selection data of different motor-control-combinations for the control-units

- IndraDrive

**Structure of the Selection Data**

The structuring of the selection data for synchronous-linear drives IndraDyn L depend on

- control unit
- Supply module / Rated connecting voltage
- Separate or parallel arrangement of the primary part

**Sorting the Lists**

The sort of the selection data depends on :

1. Motor type
2. Maximum feed force $F_{MAX}$
3. Maximum speed with maximum feedrate force $v_{FMAX}$

**Design Primary Part**

For the standard and thermal encapsulation at same size obtain the same data. The specification of the motor-control-combination result concurrent for both constructions.

☞ The specification of the data for motor-control-combination result concurrent for standard and thermal encapsulation.

**Parallel Motor Arrangement**

Motor-control-combinations are also specified for parallel motor arrangement on a drive controller.

☞ The specification of the data for parallel motor arrangement result for parallel arrangement on one drive controller. Dimensioning and selection for separate motors results from the Gantry-arrangement.

**PWM-Frequency Drive-Controller**

The PWM-Frequency of the drive controller affects the resulting motor data. All data in this documentation refer to a PWM-Frequency of 4 kHz.

### 10.1.2 Explanation of the Stated Sizes

**Maximum Feed Force**

Maximum feed force $F_{MAX}$ of the motor, available for maximum 499 ms (see fig. 4-1 "Example motor characteristic curve" on page 18).

**Maximum Velocity**

Maximum velocity $v_{FMAX}$ with maximum force $F_{MAX}$. Speed up to the maximum feedrate of the motor is available.

**Electrical Maximum Power Loss**

Electrical maximum power loss $P_{VMAX}$of the motor, referring to the stated maximum current at a motor winding temperature of 135 °C.

**Continuous Feed Force**

Continuous feed force $F_{dN}$ of the motor with regard to:

- Liquid cooling, coolant-water inlet temperature 30°C
- Motor-winding temperature 135 °C.
- Motor stillstand

**Nominal Velocity**

Nominal Velocity $V_N$

Force, which is available at a constant nominal force $F_{dN}$ of the motor.

**Nominal Power Loss**

Nominal power loss $P_{vN}$ of the motor at $F_{dN}$.

**Relative Duty Cycle**

Duty ratio $ED_{FMAX}$ in %, referring to the specified **maximum and continuous force**.

**Short Time Operation Force**

The potential short-time operation force $F_{KB}$ result from the rate between motor continuous nominal voltage and the continuous nominal voltage of the drive-controller and can be used in intermittent duty S6 with the duty ratio $ED_{FKB}$

The maximum duty cycle time complies with the thermal time constant of the motor.

$$ED_{F_{KB}} \approx \left(\frac{F_{dN}}{F_{KB}}\right)^2 \cdot 100\%$$

$F_{dN}$ Continuous nominal force of the motor in N

$F_{KB}$ Potential short-time operation force in N

*Fig. 10-1: Calculation of the potential operation time, relating on FKB*

A short-time operation force higher than the continuous nominal force of the motor is only then available, if the continuous voltage of the drive-controller is higher than the continuous nominal voltage of the motor.

**Continuous Nominal Voltage**

Continuous nominal current $I_{dN}$ of the motor at continuous nominal force $F_{dN}$.

**Maximum Current**

Maximum current $I_{max}$ of the motor at $F_{MAX}$.

The specification of the voltage results always from the effective values – as far as no others are specified.

# 10.2 Motor-Control-Combination; Separate Arrangement of the Primary Part

## 10.2.1 Controlled Constant DC Link, Rated Connecting Voltage 3 x AV 400 V

| $F_{MAX}$ [N] | $v_{Fmax}$ [m/min] | $P_{VMAX}$ [kW] | $F_{dN}$ [N] | $v_N$ [m/min] | $P_{vN}$ [kW] | $ED_{FMAX}$ [%] | $F_{KB}$ [N] | $I_{dN}$ [A] | $I_{MAX}$ [A] | Primary part Standard - / Thermal encapsulation MLP ... | Control device |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 800 | 300 | 6.8 | 250 | 500 | 0.33 | 5 | 346 | 4.2 | 20 | 040A-0300 | HMS01.1N-W0020 |
| 800 | 300 | 6.8 | 250 | 500 | 0.33 | 5 | 375 | | | | HMS01.1N-W0036 |
| 505 | 407 | 2.3 | 161 | 533 | 0.14 | 6 | 161 | | | | HCS02.1E-W0012 |
| 800 | 300 | 6.8 | 250 | 500 | 0.33 | 5 | 375 | | | | HCS02.1E-W0028 |
| 800 | 300 | 6.8 | 250 | 500 | 0.33 | 5 | 375 | | | | HCS03.1E-W0070 |
| 1150 | 150 | 10.1 | 370 | 300 | 0.39 | 5 | 506 | 4.2 | 20 | 040B-0150 | HMS01.1N-W0020 |
| 1150 | 150 | 10.1 | 370 | 300 | 0.39 | 5 | 555 | | | | HMS01.1N-W0036 |
| 732 | 231 | 3.3 | 238 | 326 | 0.2 | 6 | 238 | | | | HCS02.1E-W0012 |
| 1150 | 150 | 10.1 | 370 | 300 | 0.49 | 5 | 555 | | | | HCS02.1E-W0028 |
| 1150 | 150 | 10.1 | 370 | 300 | 0.49 | 5 | 555 | | | | HCS03.1E-W0070 |
| 898 | 299 | 5.1 | 370 | 400 | 0.4 | 8 | 428 | 5.3 | 27 | 040B-0250 | HMS01.1N-W0020 |
| 1150 | 250 | 9.2 | 370 | 400 | 0.4 | 4 | 555 | | | | HMS01.1N-W0036 |
| 1150 | 250 | 9.2 | 370 | 400 | 0.4 | 4 | 454 | | | | HCS02.1E-W0028 |
| 1150 | 250 | 9.2 | 370 | 400 | 0.4 | 4 | 555 | | | | HCS02.1E-W0054 |
| 1150 | 250 | 9.2 | 370 | 400 | 0.4 | 4 | 555 | | | | HCS03.1E-W0070 |

| $F_{MAX}$ [N] | $v_{Fmax}$ [m/min] | $P_{VMAX}$ [kW] | $F_{dN}$ [N] | $v_N$ [m/min] | $P_{vN}$ [kW] | $ED_{FMAX}$ [%] | $F_{KB}$ [N] | $I_{dN}$ [A] | $I_{MAX}$ [A] | Primary part Standard - / Thermal encapsulation MLP ... | Control device |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 747 | 404 | 3.9 | 370 | 500 | 0.4 | 10 | 395 | 6 | 35 | 040B-0350 | HMS01.1N-W0020 |
| 1150 | 300 | 11.9 | 370 | 500 | 0.4 | 3 | 555 | | | | HMS01.1N-W0036 |
| 969 | 347 | 7.8 | 370 | 500 | 0.4 | 5 | 404 | | | | HCS02.1E-W0028 |
| 1150 | 300 | 11.9 | 370 | 500 | 0.4 | 3 | 555 | | | | HCS02.1E-W0054 |
| 1150 | 300 | 11.9 | 370 | 500 | 0.4 | 3 | 555 | | | | HCS03.1E-W0070 |
| 1240 | 176 | 7 | 550 | 200 | 0.6 | 8 | 617 | 5.5 | 36 | 070A-0150 | HMS01.1N-W0020 |
| 2000 | 150 | 22.7 | 550 | 200 | 0.6 | 3 | 825 | | | | HMS01.1N-W0036 |
| 2000 | 150 | 22.7 | 550 | 200 | 0.6 | 3 | 825 | | | | HMS01.1N-W0054 |
| 1633 | 163 | 14 | 550 | 200 | 0.6 | 4 | 634 | | | | HCS02.1E-W0028 |
| 2000 | 150 | 22.7 | 550 | 200 | 0.6 | 3 | 825 | | | | HCS02.1E-W0054 |
| 2000 | 150 | 22.7 | 550 | 200 | 0.6 | 3 | 825 | | | | HCS03.1E-W0150 |
| 1107 | 306 | 2.6 | 550 | 360 | 0.28 | 11 | 576 | 6.3 | 42 | 070A-0220 | HMS01.1N-W0020 |
| 1756 | 244 | 8.3 | 550 | 360 | 0.28 | 3 | 817 | | | | HMS01.1N-W0036 |
| 2000 | 220 | 11.4 | 550 | 360 | 0.28 | 3 | 825 | | | | HMS01.1N-W0054 |
| 1443 | 274 | 5.1 | 550 | 360 | 0.28 | 6 | 590 | | | | HCS02.1E-W0028 |
| 2000 | 220 | 11.4 | 550 | 360 | 0.28 | 3 | 825 | | | | HCS02.1E-W0054 |
| 2000 | 220 | 11.4 | 550 | 360 | 0.28 | 3 | 825 | | | | HCS03.1E-W0070 |
| 1381 | 364 | 7.3 | 550 | 450 | 0.69 | 9 | 628 | 10.5 | 55 | 070A-0300 | HMS01.1N-W0036 |
| 1968 | 304 | 16.5 | 550 | 450 | 0.69 | 4 | 825 | | | | HMS01.1N-W0054 |
| 2000 | 300 | 17.1 | 550 | 450 | 0.69 | 4 | 825 | | | | HMS01.1N-W0070 |
| 1130 | 390 | 4.5 | 383 | 468 | 0.33 | 7 | 383 | | | | HCS02.1E-W0028 |
| 1968 | 304 | 16.5 | 550 | 450 | 0.69 | 4 | 601 | | | | HCS02.1E-W0054 |
| 2000 | 300 | 17.1 | 550 | 450 | 0.69 | 4 | 825 | | | | HCS02.1E-W0070 |
| 2000 | 300 | 17.1 | 550 | 450 | 0.69 | 4 | 825 | | | | HCS03.1E-W0070 |
| 1967 | 136 | 11.8 | 820 | 200 | 1 | 8 | 932 | 5.5 | 28 | 070B-0100 | HMS01.1N-W0020 |
| 2600 | 100 | 23.1 | 820 | 200 | 1 | 4 | 1230 | | | | HMS01.1N-W0036 |
| 2600 | 100 | 23.1 | 820 | 200 | 1 | 4 | 966 | | | | HCS02.1E-W0028 |
| 2600 | 100 | 23.1 | 820 | 200 | 1 | 4 | 1230 | | | | HCS02.1E-W0054 |
| 2600 | 100 | 23.1 | 820 | 200 | 1 | 4 | 1230 | | | | HCS03.1E-W0100 |
| 1519 | 181 | 7.2 | 820 | 220 | 0.67 | 9 | 876 | 5.8 | 42 | 070B-0120 | HMS01.1N-W0020 |
| 2304 | 137 | 23.2 | 820 | 220 | 0.67 | 3 | 1168 | | | | HMS01.1N-W0036 |
| 2600 | 120 | 31.6 | 820 | 220 | 0.67 | 2 | 1230 | | | | HMS01.1N-W0054 |
| 1926 | 158 | 14.4 | 820 | 220 | 0.67 | 5 | 893 | | | | HCS02.1E-W0028 |
| 2600 | 120 | 31.6 | 820 | 220 | 0.67 | 2 | 1230 | | | | HCS02.1E-W0054 |
| 2600 | 120 | 31.6 | 820 | 220 | 0.67 | 2 | 1230 | | | | HCS03.1E-W0070 |
| 1407 | 224 | 4.8 | 820 | 260 | 0.51 | 11 | 850 | 6.2 | 48 | 070B-0150 | HMS01.1N-W0020 |
| 2088 | 182 | 15.4 | 820 | 260 | 0.51 | 3 | 1103 | | | | HMS01.1N-W0036 |
| 2600 | 150 | 27.4 | 820 | 260 | 0.51 | 2 | 1230 | | | | HMS01.1N-W0054 |
| 1760 | 202 | 9.5 | 820 | 260 | 0.51 | 5 | 865 | | | | HCS02.1E-W0028 |
| 2600 | 150 | 27.4 | 820 | 260 | 0.51 | 2 | 1132 | | | | HCS02.1E-W0054 |
| 2600 | 150 | 27.4 | 820 | 260 | 0.51 | 2 | 1230 | | | | HCS02.1E-W0070 |
| 2600 | 150 | 27.4 | 820 | 260 | 0.51 | 2 | 1230 | | | | HCS03.1E-W0070 |
| 1848 | 314 | 7.6 | 820 | 400 | 0.65 | 9 | 935 | 10 | 55 | 070B-0250 | HMS01.1N-W0036 |
| 2561 | 253 | 17.1 | 820 | 400 | 0.65 | 4 | 1230 | | | | HMS01.1N-W0054 |
| 2600 | 250 | 17.1 | 820 | 400 | 0.65 | 4 | 1230 | | | | HMS01.1N-W0070 |
| 1544 | 339 | 4.7 | 559 | 419 | 0.35 | 7 | 599 | | | | HCS02.1E-W0028 |
| 2004 | 300 | 17.1 | 820 | 400 | 0.65 | 4 | 901 | | | | HCS02.1E-W0054 |
| 2600 | 250 | 17.1 | 820 | 400 | 0.65 | 4 | 1181 | | | | HCS02.1E-W0070 |
| 2600 | 250 | 17.7 | 820 | 400 | 0.65 | 4 | 1230 | | | | HCS03.1E-W0070 |

Motor-Controller-Combinations

| $F_{MAX}$ [N] | $v_{Fmax}$ [m/min] | $P_{VMAX}$ [kW] | $F_{dN}$ [N] | $v_N$ [m/min] | $P_{vN}$ [kW] | $ED_{FMAX}$ [%] | $F_{KB}$ [N] | $I_{dN}$ [A] | $I_{MAX}$ [A] | Primary part Standard - / Thermal encapsulation MLP ... | Control device |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1556 | 388 | 6.1 | 820 | 450 | 0.75 | 12 | 846 | 12 | 70 | 070B-0300 | HMS01.1N-W0036 |
| 2109 | 342 | 13.7 | 820 | 450 | 0.75 | 6 | 1230 | | | | HMS01.1N-W0054 |
| 2600 | 300 | 22.9 | 820 | 450 | 0.75 | 3 | 1193 | | | | HMS01.1N-W0070 |
| 2600 | 300 | 32.5 | 820 | 450 | 0.75 | 3 | 1230 | | | | HMS01.1N-W0110 |
| 1319 | 408 | 3.7 | 497 | 478 | 0.28 | 7 | 497 | | | | HCS02.1E-W0028 |
| 2109 | 342 | 13.7 | 820 | 450 | 0.75 | 6 | 820 | | | | HCS02.1E-W0054 |
| 2600 | 300 | 22.9 | 820 | 450 | 0.75 | 3 | 886 | | | | HCS02.1E-W0070 |
| 2600 | 300 | 22.9 | 820 | 450 | 0.75 | 3 | 1230 | | | | HCS03.1E-W0070 |
| 2600 | 300 | 22.9 | 820 | 450 | 0.75 | 3 | 1230 | | | | HCS03.1E-W0100 |
| 2727 | 145 | 14.4 | 1200 | 180 | 0.98 | 7 | 1423 | 8.9 | 55 | 070C-0120 | HMS01.1N-W0036 |
| 3744 | 121 | 32.4 | 1200 | 180 | 0.98 | 3 | 1800 | | | | HMS01.1N-W0054 |
| 3800 | 120 | 33.6 | 1200 | 180 | 0.98 | 3 | 1800 | | | | HMS01.1N-W0070 |
| 2293 | 155 | 8.9 | 981 | 185 | 0.66 | 7 | 981 | | | | HCS02.1E-W0028 |
| 3744 | 121 | 32.4 | 1200 | 180 | 0.98 | 3 | 1375 | | | | HCS02.1E-W0054 |
| 3800 | 120 | 33.6 | 1200 | 180 | 0.98 | 3 | 1375 | | | | HCS02.1E-W0070 |
| 3800 | 120 | 33.6 | 1200 | 180 | 0.98 | 3 | 1800 | | | | HCS03.1E-W0070 |
| 2284 | 208 | 10.4 | 1200 | 250 | 1.21 | 12 | 1254 | 11.7 | 70 | 070C-0150 | HMS01.1N-W0036 |
| 3088 | 178 | 23.3 | 1200 | 250 | 1.21 | 5 | 1800 | | | | HMS01.1N-W0054 |
| 3800 | 150 | 39.2 | 1200 | 250 | 1.21 | 3 | 1758 | | | | HMS01.1N-W0070 |
| 3800 | 150 | 39.2 | 1200 | 250 | 1.21 | 3 | 1800 | | | | HMS01.1N-W0110 |
| 1941 | 222 | 6.4 | 749 | 268 | 0.47 | 7 | 749 | | | | HCS02.1E-W0028 |
| 3088 | 178 | 22.3 | 1200 | 250 | 1.21 | 5 | 1216 | | | | HCS02.1E-W0054 |
| 3800 | 150 | 39.2 | 1200 | 250 | 1.21 | 3 | 1312 | | | | HCS02.1E-W0070 |
| 3800 | 150 | 39.2 | 1200 | 250 | 1.21 | 3 | 1800 | | | | HCS03.1E-W0070 |
| 1976 | 317 | 5.1 | 1187 | 351 | 0.72 | 14 | 1187 | 13 | 90 | 070C-0240 | HMS01.1N-W0036 |
| 2585 | 292 | 11.4 | 1200 | 350 | 0.74 | 6 | 1642 | | | | HMS01.1N-W0054 |
| 3124 | 269 | 19.1 | 1200 | 350 | 0.74 | 4 | 1577 | | | | HMS01.1N-W0070 |
| 3800 | 240 | 31.6 | 1200 | 350 | 0.74 | 2 | 1800 | | | | HMS01.1N-W0110 |
| 2585 | 292 | 11.4 | 1109 | 354 | 0.63 | 6 | 1109 | | | | HCS02.1E-W0054 |
| 3161 | 268 | 19.5 | 1200 | 350 | 0.74 | 4 | 1231 | | | | HCS02.1E-W0070 |
| 3124 | 269 | 19.1 | 1200 | 350 | 0.74 | 4 | 1800 | | | | HCS03.1E-W0070 |
| 3800 | 240 | 31.6 | 1200 | 350 | 0.74 | 2 | 1800 | | | | HCS03.1E-W0100 |
| 2200 | 393 | 8.5 | 1200 | 450 | 1.18 | 14 | 1402 | 19 | 110 | 070C-0300 | HMS01.1N-W0054 |
| 2657 | 366 | 14.3 | 1200 | 450 | 1.18 | 8 | 1347 | | | | HMS01.1N-W0070 |
| 3800 | 300 | 35.4 | 1200 | 450 | 1.18 | 3 | 1786 | | | | HMS01.1N-W0110 |
| 3800 | 300 | 35.4 | 1200 | 450 | 1.18 | 3 | 1800 | | | | HMS01.1N-W0150 |
| 2200 | 393 | 8.5 | 758 | 476 | 0.47 | 6 | 758 | | | | HCS02.1E-W0054 |
| 2679 | 365 | 14.7 | 879 | 469 | 0.63 | 4 | 879 | | | | HCS02.1E-W0070 |
| 2657 | 366 | 14.3 | 1200 | 450 | 1.18 | 8 | 1673 | | | | HCS03.1E-W0070 |
| 3513 | 317 | 29.2 | 1200 | 450 | 1.18 | 4 | 1800 | | | | HCS03.1E-W0100 |
| 3800 | 300 | 35.4 | 1200 | 450 | 1.18 | 3 | 1800 | | | | HCS03.1E-W0150 |
| 2280 | 124 | 9.5 | 1180 | 150 | 1.15 | 12 | 1209 | 6.6 | 38 | 100A-0090 | HMS01.1N-W0020 |
| 3588 | 94 | 30.8 | 1180 | 150 | 1.15 | 4 | 1695 | | | | HMS01.1N-W0036 |
| 3750 | 90 | 34.3 | 1180 | 150 | 1.15 | 3 | 1770 | | | | HMS01.1N-W0054 |
| 2957 | 109 | 19 | 1180 | 150 | 1.15 | 6 | 1238 | | | | HCS02.1E-W0028 |
| 3750 | 90 | 34.3 | 1180 | 150 | 1.15 | 3 | 1770 | | | | HCS02.1E-W0054 |
| 3750 | 90 | 34.3 | 1180 | 150 | 1.15 | 3 | 1770 | | | | HCS03.1E-W0070 |

| $F_{MAX}$ [N] | $v_{Fmax}$ [m/min] | $P_{VMAX}$ [kW] | $F_{dN}$ [N] | $v_N$ [m/min] | $P_{vN}$ [kW] | $ED_{FMAX}$ [%] | $F_{KB}$ [N] | $I_{dN}$ [A] | $I_{MAX}$ [A] | Primary part Standard - / Thermal encapsulation MLP ... | Control device |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2038 | 167 | 6.1 | 1023 | 194 | 0.81 | 13 | 1023 | 8 | 44 | 100A-0120 | HMS01.1N-W0020 |
| 3179 | 135 | 19.7 | 1180 | 190 | 1.08 | 5 | 1528 | | | | HMS01.1N-W0036 |
| 3750 | 120 | 29.4 | 1180 | 190 | 1.08 | 4 | 1770 | | | | HMS01.1N-W0054 |
| 2629 | 151 | 12.2 | 1076 | 193 | 0.9 | 7 | 1076 | | | | HCS02.1E-W0028 |
| 3750 | 120 | 29.4 | 1180 | 190 | 1.08 | 4 | 1651 | | | | HCS02.1E-W0054 |
| 3750 | 120 | 29.4 | 1180 | 190 | 1.08 | 4 | 1770 | | | | HCS02.1E-W0070 |
| 3750 | 120 | 29.4 | 1180 | 190 | 1.08 | 4 | 1770 | | | | HCS03.1E-W0070 |
| 2665 | 180 | 17.4 | 1180 | 220 | 1.49 | 9 | 1345 | 10 | 55 | 100A-0150 | HMS01.1N-W0036 |
| 3694 | 152 | 39.3 | 1180 | 220 | 1.49 | 4 | 1770 | | | | HMS01.1N-W0054 |
| 3750 | 150 | 40.7 | 1180 | 220 | 1.49 | 4 | 1770 | | | | HMS01.1N-W0070 |
| 2225 | 192 | 10.8 | 862 | 229 | 0.8 | 7 | 862 | | | | HCS02.1E-W0028 |
| 3694 | 152 | 39.3 | 1180 | 220 | 1.49 | 4 | 1297 | | | | HCS02.1E-W0054 |
| 3750 | 150 | 40.7 | 1180 | 220 | 1.49 | 4 | 1702 | | | | HCS02.1E-W0070 |
| 3750 | 150 | 40.7 | 1180 | 220 | 1.49 | 4 | 1770 | | | | HCS03.1E-W0150 |
| 2242 | 249 | 8.1 | 1180 | 290 | 1.01 | 12 | 1218 | 12 | 70 | 100A-0190 | HMS01.1N-W0036 |
| 3042 | 218 | 18.2 | 1180 | 290 | 1.01 | 6 | 1770 | | | | HMS01.1N-W0054 |
| 3750 | 190 | 30.6 | 1180 | 290 | 1.01 | 3 | 1719 | | | | HMS01.1N-W0070 |
| 3750 | 190 | 30.6 | 1180 | 290 | 1.01 | 3 | 1770 | | | | HMS01.1N-W0110 |
| 1901 | 262 | 5 | 715 | 308 | 0.37 | 7 | 715 | | | | HCS02.1E-W0028 |
| 3042 | 218 | 18.2 | 1180 | 290 | 0.01 | 6 | 1180 | | | | HCS02.1E-W0054 |
| 3750 | 190 | 30.6 | 1180 | 290 | 1.01 | 3 | 1276 | | | | HCS02.1E-W0070 |
| 3750 | 190 | 30.6 | 1180 | 290 | 1.01 | 3 | 1770 | | | | HCS03.1E-W0070 |
| 3362 | 161 | 11.4 | 1785 | 190 | 1.4 | 12 | 1841 | 12 | 70 | 100B-0120 | HMS01.1N-W0036 |
| 4549 | 139 | 25.6 | 1785 | 190 | 1.4 | 6 | 2678 | | | | HMS01.1N-W0054 |
| 5600 | 120 | 43 | 1785 | 190 | 1.4 | 3 | 2585 | | | | HMS01.1N-W0070 |
| 5600 | 120 | 43 | 1785 | 190 | 1.4 | 3 | 2678 | | | | HMS01.1N-W0110 |
| 2855 | 170 | 7 | 1082 | 203 | 0.52 | 7 | 1082 | | | | HCS02.1E-W0028 |
| 4549 | 139 | 25.6 | 1785 | 190 | 1.4 | 6 | 1785 | | | | HCS02.1E-W0054 |
| 5600 | 120 | 43 | 1785 | 190 | 1.4 | 3 | 1927 | | | | HCS02.1E-W0070 |
| 5600 | 120 | 43 | 1785 | 190 | 1.4 | 3 | 2678 | | | | HCS03.1E-W0070 |
| 5600 | 120 | 43 | 1785 | 190 | 1.4 | 3 | 2678 | | | | HCS03.1E-W0100 |
| 2917 | 321 | 11.4 | 1785 | 350 | 2.1 | 18 | 1930 | 22 | 130 | 100B-0250 | HMS01.1N-W0054 |
| 3481 | 306 | 19.1 | 1785 | 350 | 2.1 | 11 | 1862 | | | | HMS01.1N-W0070 |
| 4895 | 269 | 47.2 | 1785 | 350 | 2.1 | 4 | 2405 | | | | HMS01.1N-W0110 |
| 5600 | 250 | 65.9 | 1785 | 350 | 2.1 | 3 | 2678 | | | | HMS01.1N-W0150 |
| 2917 | 321 | 11.4 | 976 | 371 | 0.63 | 6 | 976 | | | | HCS02.1E-W0054 |
| 3509 | 305 | 19.5 | 1131 | 367 | 0.84 | 4 | 1131 | | | | HCS02.1E-W0070 |
| 3481 | 306 | 19.1 | 1785 | 350 | 2.1 | 11 | 2265 | | | | HCS03.1E-W0070 |
| 4541 | 278 | 39 | 1785 | 350 | 2.1 | 5 | 2678 | | | | HCS03.1E-W0100 |
| 5600 | 250 | 65.9 | 1785 | 350 | 2.1 | 3 | 2678 | | | | HCS03.1E-W0150 |
| 3754 | 146 | 15.2 | 2285 | 171 | 2.16 | 14 | 2285 | 13 | 90 | 100C-0090 | HMS01.1N-W0036 |
| 4888 | 127 | 34.1 | 2310 | 170 | 2.21 | 6 | 3132 | | | | HMS01.1N-W0054 |
| 5892 | 111 | 57.3 | 2310 | 170 | 2.21 | 4 | 3012 | | | | HMS01.1N-W0070 |
| 7150 | 90 | 94.8 | 2310 | 170 | 2.21 | 2 | 3465 | | | | HMS01.1N-W0110 |
| 4888 | 127 | 34.1 | 2134 | 173 | 1.89 | 6 | 2134 | | | | HCS02.1E-W0054 |
| 5941 | 110 | 58.6 | 2310 | 170 | 2.21 | 4 | 2368 | | | | HCS02.1E-W0070 |
| 5892 | 111 | 57.3 | 2310 | 170 | 2.21 | 4 | 3465 | | | | HCS03.1E-W0070 |
| 7150 | 90 | 94.8 | 2310 | 170 | 2.21 | 2 | 3465 | | | | HCS03.1E-W0100 |

Motor-Controller-Combinations

| $F_{MAX}$ [N] | $v_{Fmax}$ [m/min] | $P_{VMAX}$ [kW] | $F_{dN}$ [N] | $v_N$ [m/min] | $P_{vN}$ [kW] | $ED_{FMAX}$ [%] | $F_{KB}$ [N] | $I_{dN}$ [A] | $I_{MAX}$ [A] | Primary part Standard - / Thermal encapsulation MLP ... | Control device |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3765 | 169 | 9.9 | 1983 | 195 | 1.4 | 14 | 1983 | 15 | 85 | 100C-0120 | HMS01.1N-W0036 |
| 5014 | 151 | 22.2 | 2310 | 190 | 1.91 | 9 | 3079 | | | | HMS01.1N-W0054 |
| 6121 | 135 | 37.3 | 2310 | 190 | 1.91 | 5 | 2947 | | | | HMS01.1N-W0070 |
| 7150 | 120 | 54.9 | 2310 | 190 | 1.91 | 3 | 3465 | | | | HMS01.1N-W0110 |
| 5009 | 151 | 22.2 | 1852 | 197 | 1.23 | 6 | 1852 | | | | HCS02.1E-W0054 |
| 6167 | 134 | 38.1 | 2147 | 192 | 1.65 | 4 | 2147 | | | | HCS02.1E-W0070 |
| 6114 | 135 | 37.3 | 2310 | 190 | 1.91 | 5 | 3465 | | | | HCS03.1E-W0070 |
| 7150 | 120 | 54.9 | 2310 | 190 | 1.91 | 3 | 3465 | | | | HCS03.1E-W0100 |
| 3594 | 264 | 8.5 | 2310 | 290 | 1.72 | 20 | 2439 | 23 | 140 | 100C-0190 | HMS01.1N-W0054 |
| 4255 | 250 | 14.3 | 2310 | 290 | 1.72 | 12 | 2360 | | | | HMS01.1N-W0070 |
| 5910 | 216 | 35.4 | 2310 | 290 | 1.72 | 5 | 2994 | | | | HMS01.1N-W0110 |
| 7150 | 190 | 57.3 | 2310 | 290 | 1.72 | 3 | 3465 | | | | HMS01.1N-W0150 |
| 3594 | 264 | 8.5 | 1208 | 313 | 0.47 | 6 | 1208 | | | | HCS02.1E-W0054 |
| 4287 | 249 | 14.7 | 1400 | 309 | 0.63 | 4 | 1400 | | | | HCS02.1E-W0070 |
| 4255 | 250 | 14.3 | 2310 | 290 | 1.72 | 12 | 2831 | | | | HCS03.1E-W0070 |
| 5495 | 224 | 29.2 | 2310 | 290 | 1.72 | 6 | 3465 | | | | HCS03.1E-W0100 |
| 7150 | 190 | 57.3 | 2310 | 290 | 1.72 | 3 | 3465 | | | | HCS03.1E-W0150 |
| 3135 | 161 | 10.1 | 1680 | 190 | 1.26 | 12 | 1732 | 12 | 70 | 140A-0120 | HMS01.1N-W0036 |
| 4230 | 139 | 22.8 | 1680 | 190 | 1.26 | 6 | 2520 | | | | HMS01.1N-W0054 |
| 5200 | 120 | 38.2 | 1680 | 190 | 1.26 | 3 | 2418 | | | | HMS01.1N-W0070 |
| 5200 | 120 | 38.2 | 1680 | 190 | 1.26 | 3 | 2520 | | | | HMS01.1N-W0110 |
| 2667 | 170 | 6.2 | 1018 | 203 | 0.46 | 7 | 1018 | | | | HCS02.1E-W0028 |
| 4230 | 139 | 22.8 | 1680 | 190 | 1.26 | 6 | 1680 | | | | HCS02.1E-W0054 |
| 5200 | 120 | 38.2 | 1680 | 190 | 1.26 | 3 | 1811 | | | | HCS02.1E-W0070 |
| 5200 | 120 | 38.2 | 1680 | 190 | 1.26 | 3 | 2520 | | | | HCS03.1E-W0070 |
| 3986 | 139 | 10.9 | 2073 | 165 | 1.55 | 14 | 2073 | 15 | 85 | 140B-0090 | HMS01.1N-W0036 |
| 5334 | 121 | 24.5 | 2415 | 160 | 2.1 | 9 | 3245 | | | | HMS01.1N-W0054 |
| 6529 | 105 | 41.1 | 2415 | 160 | 2.1 | 5 | 3102 | | | | HMS01.1N-W0070 |
| 7650 | 90 | 60.6 | 2415 | 160 | 2.1 | 3 | 3622 | | | | HMS01.1N-W0110 |
| 5334 | 121 | 24.5 | 1937 | 167 | 1.35 | 6 | 1937 | | | | HCS02.1E-W0054 |
| 6587 | 104 | 42 | 2244 | 162 | 1.81 | 4 | 2244 | | | | HCS02.1E-W0070 |
| 6529 | 105 | 41.1 | 2415 | 160 | 2.1 | 5 | 3622 | | | | HCS03.1E-W0070 |
| 7650 | 90 | 60.6 | 2415 | 160 | 2.1 | 3 | 3622 | | | | HCS03.1E-W0100 |
| 4581 | 161 | 14.8 | 2415 | 190 | 1.84 | 12 | 2900 | 18 | 105 | 140B-0120 | HMS01.1N-W0054 |
| 5543 | 148 | 24.8 | 2415 | 190 | 1.84 | 7 | 2785 | | | | HMS01.1N-W0070 |
| 7650 | 120 | 55.9 | 2415 | 190 | 1.84 | 3 | 3622 | | | | HMS01.1N-W0110 |
| 4581 | 161 | 14.8 | 1610 | 201 | 0.82 | 6 | 1610 | | | | HCS02.1E-W0054 |
| 5590 | 148 | 25.4 | 1866 | 197 | 1.1 | 4 | 1866 | | | | HCS02.1E-W0070 |
| 5543 | 148 | 24.8 | 2415 | 190 | 1.84 | 7 | 3471 | | | | HCS03.1E-W0070 |
| 7348 | 124 | 50.7 | 2415 | 190 | 1.84 | 4 | 3622 | | | | HCS03.1E-W0100 |
| 7650 | 120 | 55.9 | 2415 | 190 | 1.84 | 3 | 3622 | | | | HCS03.1E-W0150 |
| 5912 | 86 | 12.9 | 3116 | 110 | 1.84 | 14 | 3116 | 13 | 70 | 140C-0050 | HMS01.1N-W0036 |
| 8079 | 67 | 29 | 3150 | 110 | 1.88 | 6 | 4722 | | | | HMS01.1N-W0054 |
| 10000 | 50 | 48.7 | 3150 | 110 | 1.88 | 4 | 4493 | | | | HMS01.1N-W0070 |
| 10000 | 50 | 48.7 | 3150 | 110 | 1.88 | 4 | 4725 | | | | HMS01.1N-W0110 |
| 8097 | 67 | 29 | 2910 | 112 | 1.6 | 6 | 2910 | | | | HCS02.1E-W0054 |
| 10000 | 50 | 48.7 | 3150 | 110 | 1.88 | 4 | 3291 | | | | HCS02.1E-W0070 |
| 10000 | 50 | 48.7 | 3150 | 110 | 1.88 | 4 | 4725 | | | | HCS03.1E-W0070 |
| 10000 | 50 | 48.7 | 3150 | 110 | 1.88 | 4 | 4725 | | | | HCS03.1E-W0100 |

| $F_{MAX}$ [N] | $v_{Fmax}$ [m/min] | $P_{VMAX}$ [kW] | $F_{dN}$ [N] | $v_N$ [m/min] | $P_{vN}$ [kW] | $ED_{FMAX}$ [%] | $F_{KB}$ [N] | $I_{dN}$ [A] | $I_{MAX}$ [A] | Primary part Standard - / Thermal encapsulation MLP ... | Control device |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5325 | 168 | 14.2 | 3150 | 190 | 2.4 | 17 | 3485 | 21 | 125 | 140C-0120 | HMS01.1N-W0054 |
| 6377 | 157 | 23.9 | 3150 | 190 | 2.4 | 10 | 3360 | | | | HMS01.1N-W0070 |
| 9013 | 130 | 59 | 3150 | 190 | 2.4 | 4 | 4370 | | | | HMS01.1N-W0110 |
| 10000 | 120 | 76.2 | 3150 | 190 | 2.4 | 3 | 4725 | | | | HMS01.1N-W0150 |
| 5325 | 168 | 14.2 | 1803 | 204 | 0.79 | 6 | 1803 | | | | HCS02.1E-W0054 |
| 6428 | 157 | 24.4 | 2089 | 201 | 1.06 | 4 | 2089 | | | | HCS02.1E-W0070 |
| 6377 | 157 | 23.9 | 3150 | 190 | 2.4 | 10 | 4109 | | | | HCS03.1E-W0070 |
| 8352 | 137 | 48.7 | 3150 | 190 | 2.4 | 5 | 4725 | | | | HCS03.1E-W0100 |
| 10000 | 120 | 76.2 | 3150 | 190 | 2.4 | 3 | 4725 | | | | HCS03.1E-W0150 |
| 5681 | 221 | 13.4 | 2628 | 256 | 1.78 | 13 | 2628 | 29 | 140 | 140C-0170 | HMS01.1N-W0070 |
| 8150 | 192 | 33 | 3150 | 250 | 2.56 | 8 | 3800 | | | | HMS01.1N-W0110 |
| 10000 | 170 | 53.3 | 3150 | 250 | 2.56 | 5 | 4725 | | | | HMS01.1N-W0150 |
| 5729 | 220 | 13.7 | 1514 | 269 | 0.59 | 4 | 1514 | | | | HCS02.1E-W0070 |
| 5681 | 221 | 13.4 | 3150 | 250 | 2.56 | 19 | 3556 | | | | HCS03.1E-W0070 |
| 7531 | 199 | 27.3 | 3150 | 250 | 2.56 | 9 | 4708 | | | | HCS03.1E-W0100 |
| 10000 | 170 | 53.3 | 3150 | 250 | 2.56 | 5 | 4725 | | | | HCS03.1E-W0150 |
| 6350 | 377 | 21.9 | 3150 | 400 | 3.12 | 14 | 3530 | 53.5 | 260 | 140C-0350 | HMS01.1N-W0150 |
| 8341 | 362 | 43 | 3150 | 400 | 3.12 | 7 | 4725 | | | | HMS01.1N-W0210 |
| 6350 | 377 | 21.9 | 3150 | 400 | 3.12 | 14 | 3793 | | | | HCS03.1E-W0150 |
| 8341 | 362 | 43 | 3150 | 400 | 3.12 | 7 | 4725 | | | | HCS03.1E-W0210 |
| 4445 | 138 | 11.4 | 2389 | 171 | 1.62 | 14 | 2389 | 13 | 70 | 200A-0090 | HMS01.1N-W0036 |
| 6038 | 113 | 25.6 | 2415 | 170 | 1.66 | 6 | 3571 | | | | HMS01.1N-W0054 |
| 7450 | 90 | 43 | 2415 | 170 | 1.66 | 4 | 3402 | | | | HMS01.1N-W0070 |
| 7450 | 90 | 43 | 2415 | 170 | 1.66 | 4 | 3622 | | | | HMS01.1N-W0110 |
| 6038 | 113 | 25.6 | 2231 | 173 | 1.41 | 6 | 2231 | | | | HCS02.1E-W0054 |
| 7450 | 90 | 43 | 2415 | 170 | 1.66 | 4 | 2519 | | | | HCS02.1E-W0070 |
| 7450 | 90 | 43 | 2415 | 170 | 1.66 | 4 | 3622 | | | | HCS03.1E-W0070 |
| 5073 | 153 | 13.1 | 2415 | 190 | 1.28 | 10 | 3122 | 16 | 88 | 200A-0120 | HMS01.1N-W0054 |
| 6190 | 138 | 22 | 2415 | 190 | 1.28 | 6 | 2988 | | | | HMS01.1N-W0070 |
| 7450 | 120 | 34.8 | 2415 | 190 | 1.28 | 4 | 3622 | | | | HMS01.1N-W0110 |
| 5073 | 153 | 13.1 | 1817 | 198 | 0.72 | 6 | 1817 | | | | HCS02.1E-W0054 |
| 6244 | 137 | 22.5 | 2105 | 194 | 0.97 | 4 | 2105 | | | | HCS02.1E-W0070 |
| 6190 | 138 | 22 | 2415 | 190 | 1.28 | 6 | 3622 | | | | HCS03.1E-W0070 |
| 7450 | 120 | 34.8 | 2415 | 190 | 1.28 | 4 | 3622 | | | | HCS03.1E-W0100 |
| 6463 | 76 | 14.7 | 3427 | 100 | 2.09 | 14 | 3427 | 13 | 70 | 200B-0040 | HMS01.1N-W0036 |
| 8815 | 57 | 33 | 3465 | 100 | 2.14 | 6 | 5172 | | | | HMS01.1N-W0054 |
| 10900 | 40 | 55.4 | 3465 | 100 | 2.14 | 4 | 4922 | | | | HMS01.1N-W0070 |
| 10900 | 40 | 55.4 | 3465 | 100 | 2.14 | 4 | 5198 | | | | HMS01.1N-W0110 |
| 8815 | 57 | 33 | 3201 | 102 | 1.82 | 6 | 3201 | | | | HCS02.1E-W0054 |
| 10900 | 40 | 55.4 | 3465 | 100 | 2.14 | 4 | 3618 | | | | HCS02.1E-W0070 |
| 10900 | 40 | 55.4 | 3465 | 100 | 2.14 | 4 | 5198 | | | | HCS03.1E-W0070 |
| 10900 | 40 | 55.4 | 3465 | 100 | 2.14 | 4 | 5198 | | | | HCS03.1E-W0100 |

Motor-Controller-Combinations

| $F_{MAX}$ [N] | $v_{Fmax}$ [m/min] | $P_{VMAX}$ [kW] | $F_{dN}$ [N] | $v_N$ [m/min] | $P_{vN}$ [kW] | $ED_{FMAX}$ [%] | $F_{KB}$ [N] | $I_{dN}$ [A] | $I_{MAX}$ [A] | Primary part Standard - / Thermal encapsulation MLP ... | Control device |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5671 | 169 | 97 | 3465 | 190 | 1.79 | 18 | 3747 | 22 | 130 | 200B-0120 | HMS01.1N-W0054 |
| 6771 | 159 | 16.2 | 3465 | 190 | 1.79 | 11 | 3616 | | | | HMS01.1N-W0070 |
| 9527 | 133 | 40.1 | 3465 | 190 | 1.79 | 4 | 4673 | | | | HMS01.1N-W0110 |
| 10900 | 120 | 56 | 3465 | 190 | 1.79 | 3 | 5198 | | | | HMS01.1N-W0150 |
| 5671 | 169 | 9.7 | 1894 | 205 | 0.53 | 6 | 1894 | | | | HCS02.1E-W0054 |
| 6825 | 158 | 16.6 | 2195 | 202 | 0.72 | 4 | 2195 | | | | HCS02.1E-W0070 |
| 6771 | 159 | 16.2 | 3465 | 190 | 1.79 | 11 | 4400 | | | | HCS03.1E-W0070 |
| 8836 | 140 | 33.1 | 3465 | 190 | 1.79 | 5 | 5198 | | | | HCS03.1E-W0100 |
| 10900 | 120 | 56 | 3465 | 190 | 1.79 | 3 | 5198 | | | | HCS03.1E-W0150 |
| 9179 | 132 | 25.8 | 4460 | 170 | 3.24 | 13 | 4532 | 23 | 120 | 200C-0090 | HMS01.1N-W0070 |
| 13239 | 98 | 63.7 | 4460 | 170 | 3.24 | 5 | 6088 | | | | HMS01.1N-W0110 |
| 14250 | 90 | 75.8 | 4460 | 170 | 3.24 | 4 | 6690 | | | | HMS01.1N-W0150 |
| 9258 | 131 | 26.4 | 2646 | 185 | 1.14 | 4 | 2646 | | | | HCS02.1E-W0070 |
| 9179 | 132 | 25.8 | 4460 | 170 | 3.24 | 13 | 5686 | | | | HCS03.1E-W0070 |
| 12220 | 107 | 52.6 | 4460 | 170 | 3.24 | 6 | 6690 | | | | HCS03.1E-W0100 |
| 14250 | 90 | 75.8 | 4460 | 170 | 3.24 | 4 | 6690 | | | | HCS03.1E-W0150 |
| 9863 | 151 | 40.1 | 4460 | 190 | 3.32 | 8 | 5104 | 30 | 175 | 200C-0120 | HMS01.1N-W0110 |
| 12560 | 132 | 74.6 | 4460 | 190 | 3.32 | 4 | 6690 | | | | HMS01.1N-W0150 |
| 14250 | 120 | 101.5 | 4460 | 190 | 3.32 | 3 | 6690 | | | | HMS01.1N-W0210 |
| 7214 | 170 | 16.6 | 2072 | 207 | 0.72 | 4 | 2072 | | | | HCS02.1E-W0070 |
| 9186 | 156 | 33.1 | 4460 | 190 | 3.32 | 10 | 6097 | | | | HCS03.1E-W0100 |
| 12560 | 132 | 74.6 | 4460 | 190 | 3.32 | 4 | 6690 | | | | HCS03.1E-W0150 |
| 14250 | 120 | 101.5 | 4460 | 190 | 3.32 | 3 | 6690 | | | | HCS03.1E-W0210 |
| 8281 | 201 | 26 | 3830 | 223 | 3.74 | 14 | 3830 | 46 | 210 | 200C-0170 | HMS01.1N-W0110 |
| 10666 | 188 | 48.2 | 4460 | 220 | 5.07 | 11 | 5591 | | | | HMS01.1N-W0150 |
| 14250 | 170 | 94.6 | 4460 | 220 | 5.07 | 5 | 6690 | | | | HMS01.1N-W0210 |
| 10666 | 188 | 48.2 | 4460 | 220 | 5.07 | 11 | 6064 | | | | HCS03.1E-W0150 |
| 14250 | 170 | 94.6 | 4460 | 220 | 5.07 | 5 | 6690 | | | | HCS03.1E-W0210 |
| 10131 | 110 | 26.8 | 4802 | 145 | 3.56 | 13 | 4802 | 28 | 140 | 200D-0060 | HMS01.1N-W0070 |
| 14487 | 81 | 66.1 | 5560 | 140 | 4.78 | 7 | 6814 | | | | HMS01.1N-W0110 |
| 17750 | 60 | 107 | 5560 | 140 | 4.78 | 4 | 8340 | | | | HMS01.1N-W0150 |
| 10216 | 110 | 27.4 | 2766 | 158 | 1.18 | 4 | 2766 | | | | HCS02.1E-W0070 |
| 10131 | 110 | 26.8 | 5560 | 140 | 4.78 | 18 | 6383 | | | | HCS03.1E-W0070 |
| 13394 | 89 | 54.6 | 5560 | 140 | 4.78 | 9 | 8340 | | | | HCS03.1E-W0100 |
| 17750 | 60 | 107 | 5560 | 140 | 4.78 | 4 | 8340 | | | | HCS03.1E-W0150 |
| 10317 | 149 | 37.8 | 4774 | 185 | 5.44 | 14 | 4774 | 46 | 210 | 200D-0100 | HMS01.1N-W0110 |
| 13287 | 129 | 70.2 | 5560 | 180 | 7.37 | 11 | 6969 | | | | HMS01.1N-W0150 |
| 17750 | 100 | 137.6 | 5560 | 180 | 7.37 | 5 | 8340 | | | | HMS01.1N-W0210 |
| 13287 | 129 | 70.2 | 5560 | 180 | 7.37 | 11 | 7557 | | | | HCS03.1E-W0150 |
| 17750 | 100 | 137.6 | 5560 | 180 | 7.37 | 5 | 8340 | | | | HCS03.1E-W0210 |
| 12432 | 151 | 57 | 5560 | 190 | 7.95 | 14 | 6408 | 53 | 225 | 200D-0120 | HMS01.1N-W0150 |
| 16687 | 126 | 111.8 | 5560 | 190 | 7.95 | 7 | 8340 | | | | HMS01.1N-W0210 |
| 12432 | 151 | 57 | 5560 | 190 | 7.95 | 14 | 6968 | | | | HCS03.1E-W0150 |
| 16687 | 126 | 111.8 | 5560 | 190 | 7.95 | 7 | 8340 | | | | HCS03.1E-W0210 |

| $F_{MAX}$ [N] | $v_{Fmax}$ [m/min] | $P_{VMAX}$ [kW] | $F_{dN}$ [N] | $v_N$ [m/min] | $P_{vN}$ [kW] | $ED_{FMAX}$ [%] | $F_{KB}$ [N] | $I_{dN}$ [A] | $I_{MAX}$ [A] | Primary part Standard - / Thermal encapsulation MLP ... | Control device |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 6292 | 133 | 17.6 | 3350 | 160 | 2.44 | 14 | 3944 | 19 | 110 | 300A-0090 | HMS01.1N-W0054 |
| 7636 | 121 | 29.6 | 3350 | 160 | 2.44 | 8 | 3784 | | | | HMS01.1N-W0070 |
| 11000 | 90 | 73.2 | 3350 | 160 | 2.44 | 3 | 5025 | | | | HMS01.1N-W0110 |
| 11000 | 90 | 73.2 | 3350 | 160 | 2.44 | 3 | 5025 | | | | HMS01.1N-W0150 |
| 6292 | 133 | 17.6 | 2117 | 171 | 0.97 | 6 | 2117 | | | | HCS02.1E-W0054 |
| 7701 | 120 | 30.3 | 2453 | 168 | 1.31 | 4 | 2453 | | | | HCS02.1E-W0070 |
| 7636 | 121 | 29.6 | 3350 | 160 | 2.44 | 8 | 4741 | | | | HCS03.1E-W0070 |
| 10156 | 98 | 60.4 | 3350 | 160 | 2.44 | 4 | 5025 | | | | HCS03.1E-W0100 |
| 11000 | 90 | 73.2 | 3350 | 160 | 2.44 | 3 | 5025 | | | | HCS03.1E-W0150 |
| 5414 | 171 | 11.4 | 3350 | 190 | 2.3 | 20 | 3557 | 23 | 138 | 300A-0120 | HMS01.1N-W0054 |
| 6477 | 161 | 19.1 | 3350 | 190 | 2.3 | 12 | 3430 | | | | HMS01.1N-W0070 |
| 9138 | 137 | 47.2 | 3350 | 190 | 2.3 | 5 | 4450 | | | | HMS01.1N-W0110 |
| 11000 | 120 | 74.3 | 3350 | 190 | 2.3 | 3 | 5025 | | | | HMS01.1N-W0150 |
| 5414 | 171 | 11.4 | 1752 | 205 | 0.63 | 6 | 1752 | | | | HCS02.1E-W0054 |
| 6528 | 161 | 19.5 | 2031 | 202 | 0.84 | 4 | 2031 | | | | HCS02.1E-W0070 |
| 6477 | 161 | 19.1 | 3350 | 190 | 2.3 | 12 | 4187 | | | | HCS03.1E-W0070 |
| 8470 | 143 | 39 | 3350 | 190 | 2.3 | 6 | 5025 | | | | HCS03.1E-W0100 |
| 11000 | 120 | 74.3 | 3350 | 190 | 2.3 | 3 | 5025 | | | | HCS03.1E-W0150 |
| 9331 | 114 | 25.8 | 4448 | 144 | 3.43 | 13 | 4448 | 28 | 140 | 300B-0070 | HMS01.1N-W0070 |
| 13315 | 89 | 63.7 | 5150 | 140 | 4.6 | 7 | 6297 | | | | HMS01.1N-W0110 |
| 16300 | 70 | 103.2 | 5150 | 140 | 4.6 | 4 | 7725 | | | | HMS01.1N-W0150 |
| 9409 | 113 | 26.4 | 2562 | 156 | 1.14 | 4 | 2562 | | | | HCS02.1E-W0070 |
| 9331 | 114 | 25.8 | 5150 | 140 | 4.6 | 18 | 5903 | | | | HCS03.1E-W0070 |
| 12316 | 95 | 52.6 | 5150 | 140 | 4.6 | 9 | 7725 | | | | HCS03.1E-W0100 |
| 16300 | 70 | 103.2 | 5150 | 140 | 4.6 | 4 | 7725 | | | | HCS03.1E-W0150 |
| 10071 | 159 | 30.7 | 5150 | 190 | 3.46 | 11 | 5447 | 35 | 205 | 300B-0120 | HMS01.1N-W0110 |
| 12692 | 143 | 57 | 5150 | 190 | 3.46 | 6 | 7117 | | | | HMS01.1N-W0150 |
| 16300 | 120 | 106.5 | 5150 | 190 | 3.46 | 3 | 7725 | | | | HMS01.1N-W0210 |
| 9412 | 163 | 25.3 | 5150 | 190 | 3.46 | 14 | 6411 | | | | HCS03.1E-W0100 |
| 12692 | 143 | 57 | 5150 | 190 | 3.46 | 6 | 7636 | | | | HCS03.1E-W0150 |
| 16300 | 120 | 106.6 | 5150 | 190 | 3.46 | 3 | 7725 | | | | HCS03.1E-W0210 |
| 12180 | 92 | 13.4 | 5605 | 114 | 1.78 | 13 | 5605 | 29 | 140 | 300C-0060 | HMS01.1N-W0070 |
| 17508 | 74 | 33 | 6720 | 110 | 2.56 | 5 | 8123 | | | | HMS01.1N-W0110 |
| 21500 | 60 | 53.5 | 6720 | 110 | 2.56 | 5 | 10080 | | | | HMS01.1N-W0150 |
| 12284 | 91 | 13.7 | 3229 | 122 | 0.59 | 4 | 3229 | | | | HCS02.1E-W0070 |
| 12180 | 92 | 13.4 | 6720 | 110 | 2.56 | 19 | 7596 | | | | HCS03.1E-W0070 |
| 16172 | 78 | 27.3 | 6720 | 110 | 2.56 | 9 | 10080 | | | | HCS03.1E-W0100 |
| 21500 | 60 | 53.5 | 6720 | 110 | 2.56 | 5 | 10080 | | | | HCS03.1E-W0150 |
| 12889 | 125 | 37.8 | 6720 | 150 | 4.76 | 13 | 6935 | 37 | 212 | 300C-0090 | HMS01.1N-W0110 |
| 16263 | 111 | 70.2 | 6720 | 150 | 4.76 | 7 | 9085 | | | | HMS01.1N-W0150 |
| 21333 | 91 | 137.6 | 6720 | 150 | 4.76 | 3 | 10080 | | | | HMS01.1N-W0210 |
| 12041 | 128 | 31.2 | 6720 | 150 | 4.76 | 15 | 8176 | | | | HCS03.1E-W0100 |
| 16263 | 111 | 70.2 | 6720 | 150 | 4.76 | 7 | 9754 | | | | HCS03.1E-W0150 |
| 21333 | 91 | 137.6 | 6720 | 150 | 4.76 | 3 | 10080 | | | | HCS03.1E-W0210 |

*Fig.10-2: Possible combination at separate arrangement*

# 10.3 Motor-control-combination; parallel arrangement of the primary part

## 10.3.1 Controlled constant DC link, rated connecting voltage 3 x AV 400 V

| $F_{MAX}$ [N] | $v_{Fmax}$ [m/min] | $P_{VMAX}$ [kW] | $F_{dN}$ [N] | $v_N$ [m/min] | $P_{vN}$ [kW] | $ED_{FMAX}$ [%] | $F_{KB}$ [N] | $I_{dN}$ [A] | $I_{MAX}$ [A] | Primary part Standard - / Thermal encapsulation MLP ... | Control device |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 905 | 427 | 3.4 | 415 | 516 | 0.45 | 13 | 415 | 4.2 | 20 | 040A-0300 | HMS01.1N-W0020 |
| 1460 | 326 | 11 | 500 | 500 | 0.66 | 6 | 657 | | | | HMS01.1N-W0036 |
| 1600 | 300 | 13.6 | 500 | 500 | 0.66 | 5 | 750 | | | | HMS01.1N-W0054 |
| 610 | 480 | 1.1 | 562 | 520 | 0.07 | 6 | 161 | | | | HCS02.1E-W0012 |
| 1192 | 374 | 6.8 | 512 | 500 | 0.5 | 7 | 436 | | | | HCS02.1E-W0028 |
| 1600 | 300 | 13.1 | 500 | 500 | 0.66 | 5 | 750 | | | | HCS02.1E-W0054 |
| 1600 | 300 | 13.6 | 500 | 500 | 0.66 | 5 | 750 | | | | HCS03.1E-W0070 |
| 1315 | 245 | 5 | 615 | 312 | 0.67 | 13 | 615 | 4.2 | 20 | 040B-0150 | HMS01.1N-W0020 |
| 2102 | 169 | 16.3 | 740 | 300 | 0.98 | 6 | 963 | | | | HMS01.1N-W0036 |
| 2300 | 150 | 20.1 | 740 | 300 | 0.98 | 5 | 1110 | | | | HMS01.1N-W0054 |
| 897 | 285 | 1.7 | 238 | 348 | 0.1 | 6 | 238 | | | | HCS02.1E-W0012 |
| 1722 | 206 | 10.1 | 646 | 309 | 0.74 | 7 | 646 | | | | HCS02.1E-W0028 |
| 2300 | 150 | 20.1 | 740 | 300 | 0.98 | 5 | 1097 | | | | HCS02.1E-W0054 |
| 2300 | 150 | 20.1 | 740 | 300 | 0.98 | 5 | 1110 | | | | HCS02.1E-W0070 |
| 2300 | 150 | 20.1 | 740 | 300 | 0.98 | 5 | 1110 | | | | HCS03.1E-W0070 |
| 1078 | 368 | 2.5 | 483 | 425 | 0.34 | 13 | 483 | 5.3 | 27 | 040B-0250 | HMS01.1N-W0020 |
| 1652 | 312 | 8.2 | 740 | 400 | 0.8 | 10 | 822 | | | | HMS01.1N-W0036 |
| 2300 | 250 | 18.5 | 740 | 400 | 0.8 | 4 | 1110 | | | | HMS01.1N-W0054 |
| 2300 | 250 | 18.5 | 740 | 400 | 0.8 | 4 | 1110 | | | | HMS01.1N-W0070 |
| 1375 | 339 | 5.1 | 508 | 423 | 0.37 | 7 | 508 | | | | HCS02.1E-W0028 |
| 2300 | 250 | 18.5 | 740 | 400 | 0.8 | 4 | 791 | | | | HCS02.1E-W0054 |
| 2300 | 250 | 18.5 | 740 | 400 | 0.8 | 4 | 1057 | | | | HCS02.1E-W0070 |
| 2300 | 250 | 18.5 | 740 | 400 | 0.8 | 4 | 1110 | | | | HCS03.1E-W0070 |
| 955 | 473 | 2 | 427 | 541 | 0.26 | 13 | 427 | 6 | 35 | 040B-0350 | HMS01.1N-W0020 |
| 1385 | 418 | 6.3 | 740 | 500 | 0.79 | 12 | 763 | | | | HMS01.1N-W0036 |
| 1870 | 355 | 14.2 | 740 | 500 | 0.79 | 6 | 1110 | | | | HMS01.1N-W0054 |
| 2300 | 300 | 23.9 | 740 | 500 | 0.79 | 3 | 1067 | | | | HMS01.1N-W0070 |
| 2300 | 300 | 23.9 | 740 | 500 | 0.79 | 3 | 1110 | | | | HMS01.1N-W0110 |
| 1178 | 444 | 3.9 | 448 | 538 | 0.29 | 7 | 448 | | | | HCS02.1E-W0028 |
| 1870 | 355 | 14.2 | 740 | 500 | 0.79 | 6 | 740 | | | | HCS02.1E-W0054 |
| 2300 | 300 | 23.9 | 740 | 500 | 0.79 | 3 | 798 | | | | HCS02.1E-W0070 |
| 2300 | 300 | 23.9 | 740 | 500 | 0.79 | 3 | 1110 | | | | HCS03.1E-W0070 |
| 1527 | 193 | 3.5 | 691 | 207 | 0.47 | 13 | 691 | 5.5 | 36 | 070A-0150 | HMS01.1N-W0020 |
| 2288 | 180 | 11.4 | 1100 | 200 | 1.19 | 10 | 1187 | | | | HMS01.1N-W0036 |
| 3145 | 165 | 25.6 | 1100 | 200 | 1.19 | 5 | 1650 | | | | HMS01.1N-W0054 |
| 3906 | 152 | 43 | 1100 | 200 | 1.19 | 3 | 1650 | | | | HMS01.1N-W0070 |
| 4000 | 150 | 45.5 | 1100 | 200 | 1.19 | 3 | 1650 | | | | HMS01.1N-W0110 |
| 1921 | 186 | 7 | 726 | 207 | 0.52 | 7 | 726 | | | | HCS02.1E-W0028 |
| 3145 | 165 | 25.6 | 1100 | 200 | 1.19 | 5 | 1147 | | | | HCS02.1E-W0054 |
| 3943 | 151 | 44 | 1100 | 200 | 1.19 | 3 | 1238 | | | | HCS02.1E-W0070 |
| 3906 | 152 | 43 | 1100 | 200 | 1.19 | 3 | 1650 | | | | HCS03.1E-W0070 |
| 4000 | 150 | 45.5 | 1100 | 200 | 1.19 | 3 | 1650 | | | | HCS03.1E-W0100 |

| $F_{MAX}$ [N] | $v_{Fmax}$ [m/min] | $P_{VMAX}$ [kW] | $F_{dN}$ [N] | $v_N$ [m/min] | $P_{vN}$ [kW] | $ED_{FMAX}$ [%] | $F_{KB}$ [N] | $I_{dN}$ [A] | $I_{MAX}$ [A] | Primary part Standard - / Thermal encapsulation MLP ... | Control device |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1401 | 346 | 1.3 | 606 | 384 | 0.17 | 13 | 606 | 6.3 | 42 | 070A-0220 | HMS01.1N-W0020 |
| 2050 | 314 | 4.2 | 1100 | 360 | 0.57 | 14 | 1111 | | | | HMS01.1N-W0036 |
| 2783 | 279 | 9.4 | 1100 | 360 | 0.57 | 6 | 1648 | | | | HMS01.1N-W0054 |
| 3431 | 248 | 15.8 | 1100 | 360 | 0.57 | 4 | 1571 | | | | HMS01.1N-W0070 |
| 4000 | 220 | 22.7 | 1100 | 360 | 0.57 | 3 | 1650 | | | | HMS01.1N-W0110 |
| 1737 | 329 | 2.6 | 637 | 383 | 0.19 | 7 | 637 | | | | HCS02.1E-W0028 |
| 2783 | 279 | 9.4 | 1051 | 363 | 0.52 | 6 | 1051 | | | | HCS02.1E-W0054 |
| 3463 | 246 | 16.1 | 1100 | 360 | 0.57 | 4 | 1155 | | | | HCS02.1E-W0070 |
| 3431 | 248 | 15.8 | 1100 | 360 | 0.57 | 4 | 1650 | | | | HCS03.1E-W0070 |
| 4000 | 220 | 22.7 | 1100 | 360 | 0.57 | 3 | 1650 | | | | HCS03.1E-W0100 |
| 1590 | 425 | 3.7 | 676 | 472 | 0.52 | 14 | 676 | 10.5 | 55 | 070A-0300 | HMS01.1N-W0036 |
| 2177 | 395 | 8.3 | 1100 | 450 | 1.38 | 17 | 1268 | | | | HMS01.1N-W0054 |
| 2697 | 368 | 13.9 | 1100 | 450 | 1.38 | 10 | 1206 | | | | HMS01.1N-W0070 |
| 4000 | 300 | 34.2 | 1100 | 450 | 1.38 | 4 | 1650 | | | | HMS01.1N-W0110 |
| 1339 | 438 | 2.3 | 383 | 487 | 0.17 | 7 | 383 | | | | HCS02.1E-W0028 |
| 2177 | 395 | 8.3 | 632 | 475 | 0.46 | 6 | 632 | | | | HCS02.1E-W0054 |
| 2723 | 366 | 14.2 | 732 | 469 | 0.61 | 4 | 732 | | | | HCS02.1E-W0070 |
| 2697 | 368 | 13.9 | 1100 | 450 | 1.38 | 10 | 1576 | | | | HCS03.1E-W0070 |
| 3673 | 317 | 28.3 | 1100 | 450 | 1.38 | 5 | 1650 | | | | HCS03.1E-W0100 |
| 4000 | 300 | 34.2 | 1100 | 450 | 1.38 | 4 | 1650 | | | | HCS03.1E-W0150 |
| 2351 | 180 | 5.9 | 1030 | 217 | 0.79 | 13 | 1030 | 5.5 | 28 | 070B-0100 | HMS01.1N-W0020 |
| 3616 | 145 | 19.1 | 1640 | 200 | 2 | 10 | 1786 | | | | HMS01.1N-W0036 |
| 5043 | 104 | 43 | 1640 | 200 | 2 | 5 | 2460 | | | | HMS01.1N-W0054 |
| 5200 | 100 | 46.2 | 1640 | 200 | 2 | 4 | 2460 | | | | HMS01.1N-W0070 |
| 3006 | 162 | 11.8 | 1083 | 216 | 0.87 | 7 | 1083 | | | | HCS02.1E-W0028 |
| 5043 | 104 | 43 | 1640 | 200 | 2 | 5 | 1718 | | | | HCS02.1E-W0054 |
| 5200 | 100 | 46.2 | 1640 | 200 | 2 | 4 | 2254 | | | | HCS02.1E-W0070 |
| 5200 | 100 | 46.2 | 1640 | 200 | 2 | 4 | 2460 | | | | HCS03.1E-W0070 |
| 2054 | 209 | 3.6 | 980 | 239 | 0.48 | 13 | 980 | 5.8 | 42 | 070B-0120 | HMS01.1N-W0020 |
| 2839 | 186 | 11.6 | 1640 | 220 | 1.35 | 12 | 1703 | | | | HMS01.1N-W0036 |
| 3726 | 162 | 26.2 | 1640 | 220 | 1.35 | 5 | 2353 | | | | HMS01.1N-W0054 |
| 4512 | 139 | 44 | 1640 | 220 | 1.35 | 3 | 2259 | | | | HMS01.1N-W0070 |
| 5200 | 120 | 63.3 | 1640 | 220 | 1.35 | 2 | 2460 | | | | HMS01.1N-W0110 |
| 2460 | 197 | 7.2 | 1030 | 237 | 0.53 | 7 | 1030 | | | | HCS02.1E-W0028 |
| 3726 | 162 | 26.2 | 1640 | 220 | 1.35 | 5 | 1661 | | | | HCS02.1E-W0054 |
| 4550 | 138 | 44.9 | 1640 | 220 | 1.35 | 3 | 1755 | | | | HCS02.1E-W0070 |
| 4512 | 139 | 44 | 1640 | 220 | 1.35 | 3 | 2460 | | | | HCS03.1E-W0070 |
| 5200 | 120 | 63.3 | 1640 | 220 | 1.35 | 2 | 2460 | | | | HCS03.1E-W0100 |
| 1962 | 250 | 2.4 | 913 | 283 | 0.32 | 13 | 913 | 6.2 | 48 | 070B-0150 | HMS01.1N-W0020 |
| 2643 | 229 | 7.7 | 1640 | 260 | 1.03 | 13 | 1658 | | | | HMS01.1N-W0036 |
| 3411 | 205 | 17.4 | 1640 | 260 | 1.03 | 6 | 2221 | | | | HMS01.1N-W0054 |
| 4092 | 184 | 29.1 | 1640 | 260 | 1.03 | 4 | 2140 | | | | HMS01.1N-W0070 |
| 5200 | 150 | 54.8 | 1640 | 260 | 1.03 | 2 | 2460 | | | | HMS01.1N-W0110 |
| 2315 | 239 | 4.8 | 960 | 281 | 0.35 | 7 | 960 | | | | HCS02.1E-W0028 |
| 3411 | 205 | 17.4 | 1584 | 262 | 0.96 | 6 | 1584 | | | | HCS02.1E-W0054 |
| 4125 | 183 | 29.8 | 1640 | 260 | 1.03 | 3 | 1703 | | | | HCS02.1E-W0070 |
| 4092 | 184 | 29.1 | 1640 | 260 | 1.03 | 4 | 2460 | | | | HCS03.1E-W0070 |
| 5200 | 150 | 54.8 | 1640 | 260 | 1.03 | 2 | 2460 | | | | HCS03.1E-W0100 |

Motor-Controller-Combinations

| $F_{MAX}$ [N] | $v_{Fmax}$ [m/min] | $P_{VMAX}$ [kW] | $F_{dN}$ [N] | $v_N$ [m/min] | $P_{vN}$ [kW] | $ED_{FMAX}$ [%] | $F_{KB}$ [N] | $I_{dN}$ [A] | $I_{MAX}$ [A] | Primary part Standard - / Thermal encapsulation MLP ... | Control device |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2274 | 374 | 3.8 | 1058 | 425 | 0.54 | 14 | 1058 | 10 | 55 | 070B-0250 | HMS01.1N-W0036 |
| 2987 | 343 | 8.5 | 1640 | 400 | 1.3 | 15 | 1883 | | | | HMS01.1N-W0054 |
| 3618 | 317 | 14.3 | 1640 | 400 | 1.3 | 9 | 1808 | | | | HMS01.1N-W0070 |
| 5200 | 250 | 35.4 | 1640 | 400 | 1.3 | 4 | 2414 | | | | HMS01.1N-W0110 |
| 5200 | 250 | 35.4 | 1640 | 400 | 1.3 | 4 | 2460 | | | | HMS01.1N-W0150 |
| 1970 | 386 | 2.3 | 599 | 444 | 0.17 | 7 | 599 | | | | HCS02.1E-W0028 |
| 2987 | 343 | 8.5 | 989 | 428 | 0.47 | 6 | 989 | | | | HCS02.1E-W0054 |
| 3649 | 316 | 14.7 | 1146 | 421 | 0.63 | 4 | 1146 | | | | HCS02.1E-W0070 |
| 3618 | 317 | 14.3 | 1640 | 400 | 1.3 | 9 | 2258 | | | | HCS03.1E-W0070 |
| 4803 | 267 | 29.2 | 1640 | 400 | 1.3 | 4 | 2460 | | | | HCS03.1E-W0100 |
| 5200 | 250 | 35.4 | 1640 | 400 | 1.3 | 4 | 2460 | | | | HCS03.1E-W0150 |
| 2007 | 435 | 3 | 878 | 482 | 0.43 | 14 | 878 | 12 | 70 | 070B-0300 | HMS01.1N-W0036 |
| 2560 | 411 | 6.8 | 1640 | 450 | 1.51 | 22 | 1703 | | | | HMS01.1N-W0054 |
| 3051 | 391 | 11.5 | 1640 | 450 | 1.51 | 13 | 1644 | | | | HMS01.1N-W0070 |
| 4280 | 339 | 28.3 | 1640 | 450 | 1.51 | 5 | 2115 | | | | HMS01.1N-W0110 |
| 5200 | 300 | 45.9 | 1640 | 450 | 1.51 | 3 | 2460 | | | | HMS01.1N-W0150 |
| 1770 | 445 | 1.9 | 497 | 498 | 0.14 | 7 | 497 | | | | HCS02.1E-W0028 |
| 2560 | 411 | 6.8 | 820 | 485 | 0.38 | 6 | 820 | | | | HCS02.1E-W0054 |
| 3075 | 390 | 11.7 | 950 | 479 | 0.51 | 4 | 950 | | | | HCS02.1E-W0070 |
| 3051 | 391 | 11.5 | 1650 | 450 | 1.51 | 13 | 1994 | | | | HCS03.1E-W0070 |
| 3971 | 352 | 23.4 | 1640 | 450 | 1.51 | 6 | 2460 | | | | HCS03.1E-W0100 |
| 5200 | 300 | 45.9 | 1640 | 450 | 1.51 | 3 | 2460 | | | | HCS03.1E-W0150 |
| 3425 | 168 | 7.2 | 1733 | 188 | 1.03 | 14 | 1733 | 8.9 | 55 | 070C-0120 | HMS01.1N-W0036 |
| 4442 | 157 | 16.2 | 2400 | 180 | 1.97 | 12 | 2867 | | | | HMS01.1N-W0054 |
| 5343 | 146 | 27.2 | 2400 | 180 | 1.97 | 7 | 2759 | | | | HMS01.1N-W0070 |
| 7600 | 120 | 67.6 | 2400 | 180 | 1.97 | 3 | 3600 | | | | HMS01.1N-W0110 |
| 7600 | 120 | 67.6 | 2400 | 180 | 1.97 | 3 | 3600 | | | | HMS01.1N-W0150 |
| 2990 | 173 | 4.4 | 981 | 196 | 0.33 | 7 | 981 | | | | HCS02.1E-W0028 |
| 4442 | 157 | 16.2 | 1619 | 189 | 0.9 | 6 | 1619 | | | | HCS02.1E-W0054 |
| 5387 | 146 | 27.8 | 1876 | 186 | 1.2 | 4 | 1876 | | | | HCS02.1E-W0070 |
| 5343 | 146 | 27.2 | 2400 | 180 | 1.97 | 7 | 3401 | | | | HCS03.1E-W0070 |
| 7034 | 127 | 55.6 | 2400 | 180 | 1.97 | 4 | 3600 | | | | HCS03.1E-W0100 |
| 7600 | 120 | 67.6 | 2400 | 180 | 1.97 | 3 | 3600 | | | | HCS03.1E-W0150 |
| 2964 | 239 | 5.2 | 1324 | 271 | 0.74 | 14 | 1324 | 11.7 | 70 | 070C-0150 | HMS01.1N-W0036 |
| 3768 | 224 | 11.7 | 2400 | 250 | 2.43 | 21 | 2523 | | | | HMS01.1N-W0054 |
| 4480 | 210 | 19.6 | 2400 | 250 | 2.43 | 12 | 2438 | | | | HMS01.1N-W0070 |
| 6264 | 176 | 48.4 | 2400 | 250 | 2.43 | 5 | 3122 | | | | HMS01.1N-W0110 |
| 7600 | 150 | 78.4 | 2400 | 250 | 2.43 | 3 | 3600 | | | | HMS01.1N-W0150 |
| 2621 | 246 | 3.2 | 749 | 282 | 0.24 | 7 | 749 | | | | HCS02.1E-W0028 |
| 3768 | 224 | 11.7 | 1236 | 273 | 0.64 | 6 | 1236 | | | | HCS02.1E-W0054 |
| 4515 | 209 | 20 | 1433 | 269 | 0.87 | 4 | 1433 | | | | HCS02.1E-W0070 |
| 4480 | 210 | 19.6 | 2400 | 250 | 2.43 | 12 | 2945 | | | | HCS03.1E-W0070 |
| 5816 | 184 | 40 | 2400 | 250 | 2.43 | 6 | 3600 | | | | HCS03.1E-W0100 |
| 7600 | 150 | 78.4 | 2400 | 250 | 2.43 | 3 | 3600 | | | | HCS03.1E-W0150 |

| $F_{MAX}$ [N] | $v_{Fmax}$ [m/min] | $P_{VMAX}$ [kW] | $F_{dN}$ [N] | $v_N$ [m/min] | $P_{vN}$ [kW] | $ED_{FMAX}$ [%] | $F_{KB}$ [N] | $I_{dN}$ [A] | $I_{MAX}$ [A] | Primary part Standard - / Thermal encapsulation MLP ... | Control device |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2737 | 343 | 2.5 | 1187 | 376 | 0.36 | 14 | 1187 | 13 | 90 | 070C-0240 | HMS01.1N-W0036 |
| 3345 | 330 | 5.7 | 2400 | 350 | 1.47 | 26 | 2402 | | | | HMS01.1N-W0054 |
| 3885 | 319 | 9.6 | 2230 | 354 | 1.27 | 13 | 2230 | | | | HMS01.1N-W0070 |
| 5236 | 290 | 23.6 | 2400 | 350 | 1.47 | 6 | 2856 | | | | HMS01.1N-W0110 |
| 6585 | 262 | 43.9 | 2400 | 350 | 1.47 | 3 | 3600 | | | | HMS01.1N-W0150 |
| 7600 | 240 | 63.2 | 2400 | 350 | 1.47 | 2 | 3600 | | | | HMS01.1N-W0210 |
| 3345 | 330 | 5.7 | 1109 | 378 | 0.31 | 6 | 1109 | | | | HCS02.1E-W0054 |
| 3911 | 318 | 9.8 | 1285 | 374 | 0.42 | 4 | 1285 | | | | HCS02.1E-W0070 |
| 3885 | 319 | 9.6 | 2400 | 350 | 1.47 | 15 | 2722 | | | | HCS03.1E-W0070 |
| 4897 | 297 | 19.5 | 2400 | 350 | 1.47 | 8 | 3353 | | | | HCS03.1E-W0100 |
| 6585 | 262 | 43.9 | 2400 | 350 | 1.47 | 3 | 3600 | | | | HCS03.1E-W0150 |
| 7600 | 240 | 63.2 | 2400 | 350 | 1.47 | 2 | 3600 | | | | HCS03.1E-W0210 |
| 2857 | 437 | 4.3 | 1646 | 472 | 1.11 | 26 | 1646 | 19 | 110 | 070C-0300 | HMS01.1N-W0054 |
| 3313 | 424 | 7.2 | 1526 | 476 | 0.95 | 13 | 1526 | | | | HMS01.1N-W0070 |
| 4457 | 391 | 17.7 | 2400 | 450 | 2.36 | 13 | 2442 | | | | HMS01.1N-W0110 |
| 5598 | 358 | 32.9 | 2400 | 450 | 2.36 | 7 | 3170 | | | | HMS01.1N-W0150 |
| 7313 | 308 | 64.5 | 2400 | 450 | 2.36 | 4 | 3600 | | | | HMS01.1N-W0210 |
| 2857 | 437 | 4.3 | 758 | 498 | 0.24 | 6 | 758 | | | | HCS02.1E-W0054 |
| 3335 | 423 | 7.3 | 879 | 494 | 0.32 | 4 | 879 | | | | HCS02.1E-W0070 |
| 3313 | 424 | 7.2 | 2244 | 455 | 2.06 | 29 | 2244 | | | | HCS03.1E-W0070 |
| 4170 | 399 | 14.6 | 2400 | 450 | 2.36 | 16 | 2863 | | | | HCS03.1E-W0100 |
| 5598 | 358 | 32.9 | 2400 | 450 | 2.36 | 7 | 3396 | | | | HCS03.1E-W0150 |
| 7313 | 308 | 64.5 | 2400 | 450 | 2.36 | 4 | 3600 | | | | HCS03.1E-W0210 |
| 2921 | 144 | 4.8 | 1243 | 163 | 0.64 | 13 | 1243 | 6.6 | 38 | 100A-0090 | HMS01.1N-W0020 |
| 4230 | 128 | 15.4 | 2309 | 151 | 2.2 | 14 | 2309 | | | | HMS01.1N-W0036 |
| 5706 | 111 | 34.7 | 2360 | 150 | 2.3 | 7 | 3419 | | | | HMS01.1N-W0054 |
| 7014 | 96 | 58.3 | 2360 | 150 | 2.3 | 4 | 3263 | | | | HMS01.1N-W0070 |
| 7500 | 90 | 68.6 | 2360 | 150 | 2.3 | 3 | 3540 | | | | HMS01.1N-W0110 |
| 3599 | 136 | 9.5 | 1307 | 162 | 0.7 | 7 | 1307 | | | | HCS02.1E-W0028 |
| 5706 | 111 | 34.7 | 2157 | 152 | 1.92 | 6 | 2157 | | | | HCS02.1E-W0054 |
| 7077 | 95 | 59.6 | 2360 | 150 | 2.3 | 4 | 2424 | | | | HCS02.1E-W0070 |
| 7014 | 96 | 58.3 | 2360 | 150 | 2.3 | 4 | 3540 | | | | HCS03.1E-W0070 |
| 7500 | 90 | 68.6 | 2360 | 150 | 2.3 | 3 | 3540 | | | | HCS03.1E-W0100 |
| 2648 | 186 | 3 | 1023 | 208 | 0.41 | 13 | 1023 | 8 | 44 | 100A-0120 | HMS01.1N-W0020 |
| 3789 | 171 | 9.9 | 1901 | 196 | 1.4 | 14 | 1901 | | | | HMS01.1N-W0036 |
| 5076 | 153 | 22.8 | 2360 | 190 | 2.17 | 10 | 3082 | | | | HMS01.1N-W0054 |
| 6218 | 138 | 37.3 | 2360 | 190 | 2.17 | 6 | 2948 | | | | HMS01.1N-W0070 |
| 7500 | 120 | 58.8 | 2360 | 190 | 2.17 | 4 | 3540 | | | | HMS01.1N-W0110 |
| 3239 | 178 | 6.1 | 1076 | 208 | 0.45 | 7 | 1076 | | | | HCS02.1E-W0028 |
| 5076 | 153 | 22.2 | 1775 | 198 | 1.23 | 6 | 1775 | | | | HCS02.1E-W0054 |
| 6273 | 137 | 38.1 | 2057 | 194 | 1.65 | 4 | 2057 | | | | HCS02.1E-W0070 |
| 6218 | 138 | 37.3 | 2360 | 190 | 2.17 | 6 | 3540 | | | | HCS03.1E-W0070 |
| 7500 | 120 | 58.8 | 2360 | 190 | 2.17 | 4 | 3540 | | | | HCS03.1E-W0100 |

Motor-Controller-Combinations

| $F_{MAX}$ [N] | $v_{Fmax}$ [m/min] | $P_{VMAX}$ [kW] | $F_{dN}$ [N] | $v_N$ [m/min] | $P_{vN}$ [kW] | $ED_{FMAX}$ [%] | $F_{KB}$ [N] | $I_{dN}$ [A] | $I_{MAX}$ [A] | Primary part Standard - / Thermal encapsulation MLP ... | Control device |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3276 | 208 | 8.7 | 1523 | 232 | 1.24 | 14 | 1523 | 10 | 55 | 100A-0150 | HMS01.1N-W0036 |
| 4305 | 194 | 19.6 | 2360 | 220 | 2.98 | 15 | 2711 | | | | HMS01.1N-W0054 |
| 5216 | 181 | 33 | 2360 | 220 | 2.98 | 9 | 2601 | | | | HMS01.1N-W0070 |
| 7500 | 150 | 81.4 | 2360 | 220 | 2.98 | 4 | 3478 | | | | HMS01.1N-W0110 |
| 7500 | 150 | 81.4 | 2360 | 220 | 2.98 | 4 | 3540 | | | | HMS01.1N-W0150 |
| 2836 | 214 | 5.4 | 862 | 241 | 0.4 | 7 | 862 | | | | HCS02.1E-W0028 |
| 4305 | 194 | 19.6 | 1423 | 233 | 1.08 | 6 | 1423 | | | | HCS02.1E-W0054 |
| 5261 | 181 | 33.7 | 1649 | 230 | 1.46 | 4 | 1649 | | | | HCS02.1E-W0070 |
| 5216 | 181 | 33 | 2360 | 220 | 2.98 | 9 | 3252 | | | | HCS03.1E-W0070 |
| 6927 | 158 | 67.3 | 2360 | 220 | 2.98 | 4 | 3540 | | | | HCS03.1E-W0100 |
| 7500 | 150 | 81.4 | 2360 | 220 | 2.98 | 4 | 3540 | | | | HCS03.1E-W0150 |
| 2890 | 280 | 4 | 1263 | 312 | 0.58 | 14 | 1263 | 12 | 70 | 100A-0190 | HMS01.1N-W0036 |
| 3689 | 264 | 9.1 | 2360 | 290 | 2.01 | 22 | 2451 | | | | HMS01.1N-W0054 |
| 4397 | 251 | 15.3 | 2360 | 290 | 2.01 | 13 | 2366 | | | | HMS01.1N-W0070 |
| 6171 | 216 | 37.8 | 2360 | 290 | 2.01 | 5 | 3046 | | | | HMS01.1N-W0110 |
| 7500 | 190 | 61.2 | 2360 | 290 | 2.01 | 3 | 3540 | | | | HMS01.1N-W0150 |
| 2548 | 287 | 2.5 | 715 | 322 | 0.18 | 7 | 715 | | | | HCS02.1E-W0028 |
| 3689 | 264 | 9.1 | 1180 | 313 | 0.5 | 6 | 1180 | | | | HCS02.1E-W0054 |
| 4432 | 250 | 15.6 | 1367 | 310 | 0.68 | 4 | 1367 | | | | HCS02.1E-W0070 |
| 4397 | 251 | 15.3 | 2360 | 290 | 2.01 | 13 | 2871 | | | | HCS03.1E-W0070 |
| 5726 | 225 | 31.2 | 2360 | 290 | 2.01 | 6 | 3540 | | | | HCS03.1E-W0100 |
| 7500 | 190 | 61.2 | 2360 | 290 | 2.01 | 3 | 3540 | | | | HCS03.1E-W0150 |
| 4356 | 183 | 5.7 | 1911 | 205 | 0.81 | 14 | 1911 | 12 | 70 | 100B-0120 | HMS01.1N-W0036 |
| 5543 | 172 | 12.7 | 3570 | 190 | 2.83 | 22 | 3705 | | | | HMS01.1N-W0054 |
| 6594 | 162 | 21.5 | 3570 | 190 | 2.83 | 13 | 3579 | | | | HMS01.1N-W0070 |
| 9227 | 138 | 53.1 | 3570 | 190 | 2.83 | 5 | 4589 | | | | HMS01.1N-W0110 |
| 11200 | 120 | 86 | 3570 | 190 | 2.83 | 3 | 5355 | | | | HMS01.1N-W0150 |
| 3849 | 188 | 3.5 | 1082 | 213 | 0.26 | 7 | 1082 | | | | HCS02.1E-W0028 |
| 5543 | 172 | 12.8 | 1785 | 207 | 0.71 | 6 | 1785 | | | | HCS02.1E-W0054 |
| 6645 | 162 | 22 | 2068 | 204 | 0.95 | 4 | 2068 | | | | HCS02.1E-W0070 |
| 6594 | 162 | 21.5 | 3570 | 190 | 2.83 | 13 | 4328 | | | | HCS03.1E-W0070 |
| 8567 | 144 | 43.9 | 3570 | 190 | 2.83 | 6 | 5355 | | | | HCS03.1E-W0100 |
| 11200 | 120 | 86 | 3570 | 190 | 2.83 | 3 | 5355 | | | | HCS03.1E-W0150 |
| 3925 | 346 | 5.7 | 2118 | 369 | 1.48 | 26 | 2118 | 22 | 130 | 100B-0250 | HMS01.1N-W0054 |
| 4489 | 338 | 9.6 | 1963 | 371 | 1.27 | 13 | 1963 | | | | HMS01.1N-W0070 |
| 5903 | 320 | 23.6 | 3208 | 355 | 3.4 | 14 | 3208 | | | | HMS01.1N-W0110 |
| 7315 | 301 | 43.9 | 3570 | 350 | 4.21 | 10 | 4312 | | | | HMS01.1N-W0150 |
| 9436 | 273 | 86 | 3570 | 350 | 4.21 | 5 | 5355 | | | | HMS01.1N-W0210 |
| 3925 | 346 | 5.7 | 976 | 384 | 0.31 | 6 | 976 | | | | HCS02.1E-W0054 |
| 4517 | 338 | 9.8 | 1131 | 382 | 0.42 | 4 | 1131 | | | | HCS02.1E-W0070 |
| 4489 | 338 | 9.6 | 2887 | 359 | 2.75 | 29 | 2887 | | | | HCS03.1E-W0070 |
| 5549 | 324 | 19.5 | 3570 | 350 | 4.21 | 22 | 3932 | | | | HCS03.1E-W0100 |
| 7315 | 301 | 43.9 | 3570 | 350 | 4.21 | 10 | 4592 | | | | HCS03.1E-W0150 |
| 9436 | 273 | 86 | 3570 | 350 | 4.21 | 5 | 5355 | | | | HCS03.1E-W0210 |

Motor-Controller-Combinations

| $F_{MAX}$ [N] | $v_{Fmax}$ [m/min] | $P_{VMAX}$ [kW] | $F_{dN}$ [N] | $v_N$ [m/min] | $P_{vN}$ [kW] | $ED_{FMAX}$ [%] | $F_{KB}$ [N] | $I_{dN}$ [A] | $I_{MAX}$ [A] | Primary part Standard - / Thermal encapsulation MLP ... | Control device |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5247 | 165 | 7.6 | 2285 | 189 | 1.08 | 14 | 2285 | 13 | 90 | 100C-0090 | HMS01.1N-W0036 |
| 6380 | 156 | 17.1 | 4620 | 170 | 4.42 | 26 | 4624 | | | | HMS01.1N-W0054 |
| 7384 | 147 | 28.7 | 4294 | 173 | 3.82 | 13 | 4294 | | | | HMS01.1N-W0070 |
| 9900 | 126 | 70.8 | 4620 | 170 | 4.42 | 6 | 5469 | | | | HMS01.1N-W0110 |
| 12411 | 106 | 131.6 | 4620 | 170 | 4.42 | 3 | 6930 | | | | HMS01.1N-W0150 |
| 14300 | 90 | 189.6 | 4620 | 170 | 4.42 | 2 | 6930 | | | | HMS01.1N-W0210 |
| 6380 | 156 | 17.1 | 2134 | 191 | 0.94 | 6 | 2134 | | | | HCS02.1E-W0054 |
| 7433 | 147 | 29.3 | 2473 | 188 | 1.27 | 4 | 2473 | | | | HCS02.1E-W0070 |
| 7384 | 147 | 28.7 | 4620 | 170 | 4.42 | 15 | 5220 | | | | HCS03.1E-W0070 |
| 9269 | 132 | 58.5 | 4620 | 170 | 4.42 | 8 | 6393 | | | | HCS03.1E-W0100 |
| 12411 | 106 | 131.6 | 4620 | 170 | 4.42 | 3 | 6930 | | | | HCS03.1E-W0150 |
| 14300 | 90 | 189.6 | 4620 | 170 | 4.42 | 2 | 6930 | | | | HCS03.1E-W0210 |
| 5036 | 187 | 4.9 | 1983 | 209 | 0.7 | 14 | 1983 | 15 | 85 | 100C-0120 | HMS01.1N-W0036 |
| 6282 | 178 | 11.1 | 4021 | 194 | 2.89 | 26 | 4021 | | | | HMS01.1N-W0054 |
| 7387 | 170 | 18.6 | 3727 | 197 | 2.48 | 13 | 3727 | | | | HMS01.1N-W0070 |
| 10154 | 150 | 46 | 4620 | 190 | 3.81 | 8 | 5280 | | | | HMS01.1N-W0110 |
| 12916 | 130 | 85.5 | 4620 | 190 | 3.81 | 4 | 6930 | | | | HMS01.1N-W0150 |
| 14300 | 120 | 109.9 | 4620 | 190 | 3.81 | 3 | 6930 | | | | HMS01.1N-W0210 |
| 6282 | 178 | 11.1 | 1852 | 210 | 0.61 | 6 | 1852 | | | | HCS02.1E-W0054 |
| 7441 | 170 | 19.1 | 2147 | 208 | 0.82 | 4 | 2147 | | | | HCS02.1E-W0070 |
| 7387 | 170 | 18.6 | 4620 | 190 | 3.81 | 20 | 5006 | | | | HCS03.1E-W0070 |
| 9470 | 155 | 38 | 4620 | 190 | 3.81 | 10 | 6297 | | | | HCS03.1E-W0100 |
| 12916 | 130 | 85.5 | 4620 | 190 | 3.81 | 4 | 6930 | | | | HCS03.1E-W0150 |
| 14300 | 120 | 109.9 | 4620 | 190 | 3.81 | 3 | 6930 | | | | HCS03.1E-W0210 |
| 4953 | 287 | 4.3 | 2623 | 311 | 1.11 | 26 | 2623 | 23 | 140 | 100C-0190 | HMS01.1N-W0054 |
| 5614 | 280 | 7.2 | 2431 | 313 | 0.95 | 13 | 2431 | | | | HMS01.1N-W0070 |
| 7270 | 263 | 17.7 | 3973 | 297 | 2.55 | 14 | 3973 | | | | HMS01.1N-W0110 |
| 8922 | 246 | 32.9 | 4620 | 290 | 3.45 | 10 | 5407 | | | | HMS01.1N-W0150 |
| 11405 | 220 | 64.5 | 4620 | 290 | 3.45 | 5 | 6930 | | | | HMS01.1N-W0210 |
| 4953 | 287 | 4.3 | 1208 | 325 | 0.24 | 6 | 1208 | | | | HCS02.1E-W0054 |
| 5646 | 280 | 7.3 | 1400 | 323 | 0.32 | 4 | 1400 | | | | HCS02.1E-W0070 |
| 5614 | 280 | 7.2 | 3575 | 301 | 2.06 | 29 | 3575 | | | | HCS03.1E-W0070 |
| 6854 | 267 | 14.6 | 4620 | 290 | 3.45 | 24 | 4962 | | | | HCS03.1E-W0100 |
| 8922 | 246 | 32.9 | 4620 | 290 | 3.45 | 10 | 5734 | | | | HCS03.1E-W0150 |
| 11405 | 220 | 64.5 | 4620 | 290 | 3.45 | 5 | 6930 | | | | HCS03.1E-W0210 |
| 4085 | 183 | 5.1 | 1799 | 206 | 0.72 | 14 | 1799 | 12 | 70 | 140A-0120 | HMS01.1N-W0036 |
| 5180 | 172 | 11.4 | 3360 | 190 | 2.51 | 22 | 3484 | | | | HMS01.1N-W0054 |
| 6150 | 162 | 19.1 | 3360 | 190 | 2.51 | 13 | 3369 | | | | HMS01.1N-W0070 |
| 8580 | 138 | 47.2 | 3360 | 190 | 2.51 | 5 | 4300 | | | | HMS01.1N-W0110 |
| 10400 | 120 | 76.4 | 3360 | 190 | 2.51 | 3 | 5040 | | | | HMS01.1N-W0150 |
| 3618 | 188 | 3.1 | 1018 | 213 | 0.23 | 7 | 1018 | | | | HCS02.1E-W0028 |
| 5180 | 172 | 11.4 | 1680 | 207 | 0.63 | 6 | 1680 | | | | HCS02.1E-W0054 |
| 6197 | 162 | 19.5 | 1947 | 204 | 0.84 | 4 | 1947 | | | | HCS02.1E-W0070 |
| 6150 | 162 | 19.1 | 3360 | 190 | 2.51 | 13 | 4060 | | | | HCS03.1E-W0070 |
| 7970 | 144 | 39 | 3360 | 190 | 2.51 | 6 | 5040 | | | | HCS03.1E-W0100 |
| 10400 | 120 | 76.4 | 3360 | 190 | 2.51 | 3 | 5040 | | | | HCS03.1E-W0150 |

Motor-Controller-Combinations

| $F_{MAX}$ [N] | $v_{Fmax}$ [m/min] | $P_{VMAX}$ [kW] | $F_{dN}$ [N] | $v_N$ [m/min] | $P_{vN}$ [kW] | $ED_{FMAX}$ [%] | $F_{KB}$ [N] | $I_{dN}$ [A] | $I_{MAX}$ [A] | Primary part Standard - / Thermal encapsulation MLP ... | Control device |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5279 | 157 | 5.4 | 2073 | 179 | 0.77 | 14 | 2073 | 15 | 85 | 140B-0090 | HMS01.1N-W0036 |
| 6628 | 148 | 12.2 | 4203 | 164 | 3.18 | 26 | 4203 | | | | HMS01.1N-W0054 |
| 7823 | 140 | 20.5 | 3896 | 166 | 2.73 | 13 | 3896 | | | | HMS01.1N-W0070 |
| 10816 | 120 | 50.8 | 4830 | 160 | 4.2 | 8 | 5544 | | | | HMS01.1N-W0110 |
| 13804 | 100 | 94.3 | 4830 | 160 | 4.2 | 4 | 7245 | | | | HMS01.1N-W0150 |
| 15300 | 90 | 121.1 | 4830 | 160 | 4.2 | 3 | 7245 | | | | HMS01.1N-W0210 |
| 6628 | 148 | 12.2 | 1937 | 179 | 0.68 | 6 | 1937 | | | | HCS02.1E-W0054 |
| 7881 | 140 | 21 | 2244 | 177 | 0.91 | 4 | 2244 | | | | HCS02.1E-W0070 |
| 7823 | 140 | 20.5 | 4830 | 160 | 4.2 | 20 | 5248 | | | | HCS03.1E-W0070 |
| 10065 | 125 | 41.9 | 4830 | 160 | 4.2 | 10 | 6644 | | | | HCS03.1E-W0100 |
| 13804 | 100 | 94.3 | 4830 | 160 | 4.2 | 4 | 7245 | | | | HCS03.1E-W0150 |
| 15300 | 90 | 121.1 | 4830 | 160 | 4.2 | 3 | 7245 | | | | HCS03.1E-W0210 |
| 5911 | 183 | 7.4 | 3495 | 199 | 1.92 | 26 | 3495 | 18 | 105 | 140B-0120 | HMS01.1N-W0054 |
| 6873 | 176 | 12.4 | 3239 | 201 | 1.65 | 13 | 3239 | | | | HMS01.1N-W0070 |
| 9282 | 160 | 30.7 | 4830 | 190 | 3.68 | 12 | 5039 | | | | HMS01.1N-W0110 |
| 11687 | 144 | 57 | 4830 | 190 | 3.68 | 6 | 6571 | | | | HMS01.1N-W0150 |
| 15300 | 120 | 111.1 | 4830 | 190 | 3.68 | 3 | 7245 | | | | HMS01.1N-W0210 |
| 5911 | 183 | 7.4 | 1610 | 212 | 0.41 | 6 | 1610 | | | | HCS02.1E-W0054 |
| 6920 | 176 | 12.7 | 1866 | 210 | 0.55 | 4 | 1866 | | | | HCS02.1E-W0070 |
| 6873 | 176 | 12.4 | 4764 | 191 | 3.58 | 29 | 4764 | | | | HCS03.1E-W0070 |
| 8678 | 164 | 25.3 | 4830 | 190 | 3.68 | 15 | 5924 | | | | HCS03.1E-W0100 |
| 11687 | 144 | 57 | 4830 | 190 | 3.68 | 6 | 7047 | | | | HCS03.1E-W0150 |
| 15300 | 120 | 111.8 | 4830 | 190 | 3.68 | 3 | 7245 | | | | HCS03.1E-W0210 |
| 7498 | 105 | 6.4 | 3116 | 124 | 0.92 | 14 | 3116 | 13 | 70 | 140C-0050 | HMS01.1N-W0036 |
| 9666 | 95 | 14.5 | 6300 | 110 | 3.76 | 26 | 6308 | | | | HMS01.1N-W0054 |
| 11586 | 87 | 24.4 | 5855 | 112 | 3.24 | 13 | 5855 | | | | HMS01.1N-W0070 |
| 16397 | 66 | 60.2 | 6300 | 110 | 3.76 | 6 | 7923 | | | | HMS01.1N-W0110 |
| 20000 | 50 | 91.5 | 6300 | 110 | 3.76 | 4 | 9450 | | | | HMS01.1N-W0150 |
| 9666 | 95 | 14.5 | 2910 | 125 | 0.8 | 6 | 2910 | | | | HCS02.1E-W0054 |
| 11680 | 86 | 24.9 | 3373 | 123 | 1.08 | 4 | 3373 | | | | HCS02.1E-W0070 |
| 11586 | 87 | 24.4 | 6300 | 110 | 3.76 | 15 | 7447 | | | | HCS03.1E-W0070 |
| 15190 | 71 | 49.7 | 6300 | 110 | 3.76 | 8 | 9450 | | | | HCS03.1E-W0100 |
| 20000 | 50 | 97.5 | 6300 | 110 | 3.76 | 4 | 9450 | | | | HCS03.1E-W0150 |
| 7092 | 186 | 7.1 | 3914 | 202 | 1.85 | 26 | 3914 | 21 | 125 | 140C-0120 | HMS01.1N-W0054 |
| 8144 | 181 | 11.9 | 3627 | 204 | 1.59 | 13 | 3627 | | | | HMS01.1N-W0070 |
| 10780 | 167 | 29.5 | 5929 | 192 | 4.25 | 14 | 5929 | | | | HMS01.1N-W0110 |
| 13411 | 154 | 54.8 | 6300 | 190 | 4.8 | 9 | 7813 | | | | HMS01.1N-W0150 |
| 17364 | 134 | 107.5 | 6300 | 190 | 4.8 | 4 | 9450 | | | | HMS01.1N-W0210 |
| 7092 | 186 | 7.1 | 1803 | 213 | 0.39 | 6 | 1803 | | | | HCS02.1E-W0054 |
| 8195 | 180 | 12.2 | 2089 | 212 | 0.53 | 4 | 2089 | | | | HCS02.1E-W0070 |
| 8144 | 181 | 11.9 | 5335 | 195 | 3.44 | 29 | 5335 | | | | HCS03.1E-W0070 |
| 10118 | 171 | 24.4 | 6300 | 190 | 4.8 | 20 | 7106 | | | | HCS03.1E-W0100 |
| 13411 | 154 | 54.8 | 6300 | 190 | 4.8 | 9 | 8335 | | | | HCS03.1E-W0150 |
| 17364 | 134 | 107.5 | 6300 | 190 | 4.8 | 4 | 9450 | | | | HCS03.1E-W0210 |

| $F_{MAX}$ [N] | $v_{Fmax}$ [m/min] | $P_{VMAX}$ [kW] | $F_{dN}$ [N] | $v_N$ [m/min] | $P_{vN}$ [kW] | $ED_{FMAX}$ [%] | $F_{KB}$ [N] | $I_{dN}$ [A] | $I_{MAX}$ [A] | Primary part Standard - / Thermal encapsulation MLP ... | Control device |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 7042 | 246 | 6.7 | 2628 | 272 | 0.89 | 13 | 2628 | 29 | 140 | 140C-0170 | HMS01.1N-W0070 |
| 9511 | 231 | 16.5 | 4295 | 262 | 2.38 | 14 | 4295 | | | | HMS01.1N-W0110 |
| 11976 | 217 | 30.7 | 6300 | 250 | 5.12 | 17 | 6732 | | | | HMS01.1N-W0150 |
| 15681 | 195 | 60.2 | 6300 | 250 | 5.12 | 9 | 9201 | | | | HMS01.1N-W0210 |
| 7090 | 246 | 6.8 | 1514 | 278 | 0.3 | 4 | 1514 | | | | HCS02.1E-W0070 |
| 7042 | 246 | 6.7 | 3865 | 264 | 1.93 | 29 | 3865 | | | | HCS03.1E-W0070 |
| 8892 | 235 | 13.6 | 5893 | 253 | 4.48 | 33 | 5893 | | | | HCS03.1E-W0100 |
| 11976 | 217 | 30.7 | 6300 | 250 | 5.12 | 17 | 7221 | | | | HCS03.1E-W0150 |
| 15681 | 195 | 60.2 | 6300 | 250 | 5.12 | 9 | 9450 | | | | HCS03.1E-W0210 |
| 7724 | 395 | 11 | 3824 | 409 | 2.3 | 21 | 3824 | 53.5 | 260 | 140C-0350 | HMS01.1N-W0150 |
| 9716 | 388 | 21.5 | 6179 | 401 | 6 | 28 | 6179 | | | | HMS01.1N-W0210 |
| 7724 | 395 | 11 | 4290 | 408 | 2.89 | 26 | 4290 | | | | HCS03.1E-W0150 |
| 9716 | 388 | 21.5 | 6300 | 400 | 6.23 | 29 | 6574 | | | | HCS03.1E-W0210 |
| 5711 | 163 | 5.7 | 2389 | 190 | 0.81 | 14 | 2389 | 13 | 70 | 200A-0090 | HMS01.1N-W0036 |
| 7304 | 150 | 12.8 | 4830 | 170 | 3.31 | 26 | 4836 | | | | HMS01.1N-W0054 |
| 8716 | 139 | 21.5 | 4489 | 173 | 2.86 | 13 | 4489 | | | | HMS01.1N-W0070 |
| 12251 | 111 | 53.1 | 4830 | 170 | 3.31 | 6 | 6023 | | | | HMS01.1N-W0110 |
| 14900 | 90 | 86 | 4830 | 170 | 3.31 | 4 | 7245 | | | | HMS01.1N-W0150 |
| 7304 | 150 | 12.8 | 2231 | 191 | 0.71 | 6 | 2231 | | | | HCS02.1E-W0054 |
| 8784 | 139 | 22 | 2586 | 188 | 0.95 | 4 | 2586 | | | | HCS02.1E-W0070 |
| 8716 | 139 | 21.5 | 4830 | 170 | 3.31 | 15 | 5673 | | | | HCS03.1E-W0070 |
| 11364 | 118 | 43.9 | 4830 | 170 | 3.31 | 8 | 7245 | | | | HCS03.1E-W0100 |
| 14900 | 90 | 86 | 4830 | 170 | 3.31 | 4 | 7245 | | | | HCS03.1E-W0150 |
| 6379 | 179 | 6.5 | 3943 | 196 | 1.7 | 26 | 3943 | 16 | 88 | 200A-0120 | HMS01.1N-W0054 |
| 7488 | 172 | 11 | 3655 | 198 | 1.46 | 13 | 3655 | | | | HMS01.1N-W0070 |
| 10285 | 152 | 27.1 | 4830 | 190 | 2.56 | 9 | 5359 | | | | HMS01.1N-W0110 |
| 13077 | 132 | 50.4 | 4830 | 190 | 2.56 | 5 | 7138 | | | | HMS01.1N-W0150 |
| 14900 | 120 | 69.5 | 4830 | 190 | 2.56 | 4 | 7245 | | | | HMS01.1N-W0210 |
| 6372 | 179 | 6.5 | 1817 | 211 | 0.36 | 6 | 1817 | | | | HCS02.1E-W0054 |
| 7543 | 171 | 11.2 | 2105 | 209 | 0.49 | 4 | 2105 | | | | HCS02.1E-W0070 |
| 7488 | 172 | 11 | 4830 | 190 | 2.56 | 23 | 5082 | | | | HCS03.1E-W0070 |
| 9583 | 157 | 22.4 | 4830 | 190 | 2.56 | 11 | 6386 | | | | HCS03.1E-W0100 |
| 13077 | 133 | 50.4 | 4830 | 190 | 2.56 | 5 | 7245 | | | | HCS03.1E-W0150 |
| 14900 | 120 | 69.5 | 4830 | 190 | 2.56 | 4 | 7245 | | | | HCS03.1E-W0210 |
| 8231 | 95 | 7.3 | 3427 | 114 | 1.04 | 14 | 3427 | 13 | 70 | 200B-0040 | HMS01.1N-W0036 |
| 10583 | 85 | 16.5 | 6930 | 100 | 4.27 | 26 | 6939 | | | | HMS01.1N-W0054 |
| 12668 | 77 | 27.7 | 6440 | 102 | 3.69 | 13 | 6440 | | | | HMS01.1N-W0070 |
| 17889 | 56 | 68.5 | 6930 | 100 | 4.27 | 6 | 8692 | | | | HMS01.1N-W0110 |
| 21800 | 40 | 110.8 | 6930 | 100 | 4.27 | 4 | 10395 | | | | HMS01.1N-W0150 |
| 10583 | 5 | 16.5 | 3201 | 115 | 0.91 | 6 | 3201 | | | | HCS02.1E-W0054 |
| 12769 | 76 | 28.3 | 3710 | 113 | 1.22 | 4 | 3710 | | | | HCS02.1E-W0070 |
| 12668 | 77 | 27.7 | 6930 | 100 | 4.27 | 15 | 8175 | | | | HCS03.1E-W0070 |
| 16579 | 61 | 56.5 | 6930 | 100 | 4.27 | 8 | 10395 | | | | HCS03.1E-W0100 |
| 21800 | 40 | 110.8 | 6930 | 100 | 4.27 | 4 | 10395 | | | | HCS03.1E-W0150 |

Motor-Controller-Combinations

| $F_{MAX}$ [N] | $v_{Fmax}$ [m/min] | $P_{VMAX}$ [kW] | $F_{dN}$ [N] | $v_N$ [m/min] | $P_{vN}$ [kW] | $ED_{FMAX}$ [%] | $F_{KB}$ [N] | $I_{dN}$ [A] | $I_{MAX}$ [A] | Primary part Standard - / Thermal encapsulation MLP ... | Control device |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 7621 | 187 | 4.8 | 4111 | 203 | 1.26 | 26 | 4111 | | | | HMS01.1N-W0054 |
| 8722 | 182 | 8.1 | 3810 | 205 | 1.08 | 13 | 3810 | | | | HMS01.1N-W0070 |
| 11478 | 169 | 20.1 | 6228 | 193 | 2.89 | 14 | 6228 | | | | HMS01.1N-W0110 |
| 14229 | 156 | 37.3 | 6930 | 190 | 3.58 | 10 | 8376 | | | | HMS01.1N-W0150 |
| 18362 | 136 | 73.1 | 6930 | 190 | 3.58 | 5 | 10395 | | | | HMS01.1N-W0210 |
| 7621 | 187 | 4.8 | 1894 | 214 | 0.27 | 6 | 1894 | 22 | 130 | 200B-0120 | HCS02.1E-W0054 |
| 8775 | 181 | 8.3 | 2195 | 212 | 0.36 | 4 | 2195 | | | | HCS02.1E-W0070 |
| 8722 | 182 | 8.1 | 5604 | 196 | 2.34 | 29 | 5604 | | | | HCS03.1E-W0070 |
| 10786 | 172 | 16.6 | 6930 | 190 | 3.58 | 22 | 7636 | | | | HCS03.1E-W0100 |
| 14229 | 156 | 37.3 | 6930 | 190 | 3.58 | 10 | 8921 | | | | HCS03.1E-W0150 |
| 18362 | 136 | 73.1 | 6930 | 190 | 3.58 | 5 | 10395 | | | | HCS03.1E-W0210 |
| 11258 | 161 | 12.9 | 4594 | 188 | 1.72 | 13 | 4594 | | | | HMS01.1N-W0070 |
| 15318 | 144 | 31.9 | 7509 | 176 | 4.59 | 14 | 7509 | | | | HMS01.1N-W0110 |
| 19370 | 127 | 59.2 | 8920 | 170 | 6.47 | 11 | 10749 | | | | HMS01.1N-W0150 |
| 25459 | 102 | 116.1 | 8920 | 170 | 6.47 | 6 | 13380 | | | | HMS01.1N-W0210 |
| 11337 | 160 | 13.2 | 2646 | 196 | 0.57 | 4 | 2646 | 23 | 120 | 200C-0090 | HCS02.1E-W0070 |
| 11258 | 161 | 12.9 | 6757 | 179 | 3.71 | 29 | 6757 | | | | HCS03.1E-W0070 |
| 14299 | 148 | 26.3 | 8920 | 170 | 6.47 | 25 | 9659 | | | | HCS03.1E-W0100 |
| 19370 | 127 | 59.2 | 8920 | 170 | 6.47 | 11 | 11552 | | | | HCS03.1E-W0150 |
| 25459 | 102 | 116.1 | 8920 | 170 | 6.47 | 6 | 13380 | | | | HCS03.1E-W0210 |
| 12299 | 178 | 20.1 | 5880 | 201 | 2.89 | 14 | 5880 | | | | HMS01.1N-W0110 |
| 14996 | 168 | 37.3 | 8920 | 190 | 6.65 | 18 | 9259 | | | | HMS01.1N-W0150 |
| 19049 | 154 | 73.1 | 8920 | 190 | 6.65 | 9 | 11961 | | | | HMS01.1N-W0210 |
| 9650 | 188 | 8.3 | 2072 | 215 | 0.36 | 4 | 2072 | 30 | 175 | 200C-0120 | HCS02.1E-W0070 |
| 11622 | 180 | 16.6 | 8068 | 193 | 5.44 | 33 | 8068 | | | | HCS03.1E-W0100 |
| 14996 | 168 | 37.3 | 8920 | 190 | 6.65 | 18 | 9794 | | | | HCS03.1E-W0150 |
| 19049 | 154 | 73.1 | 8920 | 190 | 6.65 | 9 | 12457 | | | | HCS03.1E-W0210 |
| 9992 | 217 | 13 | 3830 | 233 | 1.87 | 14 | 3830 | | | | HMS01.1N-W0110 |
| 12378 | 211 | 24.1 | 6296 | 227 | 5.05 | 21 | 6296 | | | | HMS01.1N-W0150 |
| 15962 | 202 | 47.3 | 8920 | 220 | 10.14 | 21 | 9693 | 46 | 210 | 200C-0170 | HMS01.1N-W0210 |
| 12378 | 211 | 24.1 | 7063 | 225 | 6.36 | 26 | 7063 | | | | HCS03.1E-W0150 |
| 15962 | 202 | 47.3 | 8920 | 220 | 10.14 | 21 | 10309 | | | | HCS03.1E-W0210 |
| 12644 | 135 | 13.4 | 4802 | 161 | 1.78 | 13 | 4802 | | | | HMS01.1N-W0070 |
| 17000 | 121 | 33 | 7849 | 151 | 4.76 | 14 | 7849 | | | | HMS01.1N-W0110 |
| 21348 | 107 | 61.4 | 11120 | 140 | 9.55 | 16 | 12097 | | | | HMS01.1N-W0150 |
| 27881 | 85 | 120.4 | 11120 | 140 | 9.55 | 8 | 16453 | | | | HMS01.1N-W0210 |
| 12728 | 135 | 13.7 | 2766 | 168 | 0.59 | 4 | 2766 | 28 | 140 | 200D-0060 | HCS02.1E-W0070 |
| 12644 | 135 | 13.4 | 7062 | 153 | 3.85 | 29 | 7062 | | | | HCS03.1E-W0070 |
| 15907 | 124 | 27.3 | 10769 | 141 | 8.96 | 33 | 10769 | | | | HCS03.1E-W0100 |
| 21348 | 107 | 61.4 | 11120 | 140 | 9.55 | 16 | 12959 | | | | HCS03.1E-W0150 |
| 27881 | 85 | 120.4 | 11120 | 140 | 9.55 | 8 | 16680 | | | | HCS03.1E-W0210 |
| 12455 | 176 | 18.9 | 4774 | 201 | 2.72 | 14 | 4774 | | | | HMS01.1N-W0110 |
| 15425 | 166 | 35.1 | 7849 | 191 | 7.35 | 21 | 7849 | | | | HMS01.1N-W0150 |
| 19888 | 151 | 68.8 | 11120 | 180 | 14.75 | 21 | 12082 | 46 | 210 | 200D-0100 | HMS01.1N-W0210 |
| 15425 | 166 | 35.1 | 8805 | 188 | 9.25 | 26 | 88,5 | | | | HCS03.1E-W0150 |
| 19888 | 151 | 68.8 | 11120 | 180 | 14.75 | 21 | 12849 | | | | HCS03.1E-W0210 |

| $F_{MAX}$ [N] | $v_{Fmax}$ [m/min] | $P_{VMAX}$ [kW] | $F_{dN}$ [N] | $v_N$ [m/min] | $P_{vN}$ [kW] | $ED_{FMAX}$ [%] | $F_{KB}$ [N] | $I_{dN}$ [A] | $I_{MAX}$ [A] | Primary part Standard - / Thermal encapsulation MLP ... | Control device |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 14233 | 181 | 28.5 | 6813 | 202 | 5.97 | 21 | 6813 | 53 | 225 | 200D-0120 | HMS01.1N-W0150 |
| 18488 | 169 | 55.9 | 11009 | 190 | 15.59 | 28 | 11009 | | | | HMS01.1N-W0210 |
| 14233 | 181 | 28.5 | 7643 | 202 | 7.51 | 26 | 7643 | | | | HCS03.1E-W0150 |
| 18488 | 169 | 55.9 | 11120 | 190 | 15.9 | 28 | 11777 | | | | HCS03.1E-W0210 |
| 8043 | 154 | 8.8 | 4595 | 170 | 2.3 | 26 | 4595 | 19 | 110 | 300A-0090 | HMS01.1N-W0054 |
| 9378 | 148 | 14.8 | 4259 | 171 | 1.97 | 13 | 4259 | | | | HMS01.1N-W0070 |
| 12751 | 132 | 36.6 | 6700 | 160 | 4.88 | 13 | 6825 | | | | HMS01.1N-W0110 |
| 16109 | 117 | 68 | 6700 | 160 | 4.88 | 7 | 8965 | | | | HMS01.1N-W0150 |
| 21156 | 94 | 133.3 | 6700 | 160 | 4.88 | 4 | 10050 | | | | HMS01.1N-W0210 |
| 8043 | 154 | 8.8 | 2117 | 181 | 0.49 | 6 | 2117 | | | | HCS02.1E-W0054 |
| 9452 | 148 | 15.1 | 2453 | 180 | 0.65 | 4 | 2453 | | | | HCS02.1E-W0070 |
| 9378 | 148 | 14.8 | 6264 | 162 | 4.26 | 29 | 6264 | | | | HCS03.1E-W0070 |
| 11907 | 136 | 30.2 | 6700 | 160 | 4.88 | 16 | 8061 | | | | HCS03.1E-W0100 |
| 16109 | 117 | 68 | 6700 | 160 | 4.88 | 7 | 9630 | | | | HCS03.1E-W0150 |
| 21156 | 94 | 133.3 | 6700 | 160 | 4.88 | 4 | 10050 | | | | HCS03.1E-W0210 |
| 7236 | 188 | 5.7 | 3804 | 203 | 1.48 | 26 | 3804 | 23 | 138 | 300A-0120 | HMS01.1N-W0054 |
| 8299 | 183 | 9.6 | 3525 | 205 | 1.27 | 13 | 3525 | | | | HMS01.1N-W0070 |
| 10960 | 171 | 23.6 | 5762 | 194 | 3.4 | 14 | 5762 | | | | HMS01.1N-W0110 |
| 13617 | 158 | 43.9 | 6700 | 190 | 4.59 | 10 | 7965 | | | | HMS01.1N-W0150 |
| 17608 | 140 | 86 | 6700 | 190 | 4.59 | 5 | 10050 | | | | HMS01.1N-W0210 |
| 7236 | 188 | 5.7 | 1752 | 213 | 0.31 | 6 | 1752 | | | | HCS02.1E-W0054 |
| 8350 | 183 | 9.8 | 2031 | 211 | 0.42 | 4 | 2031 | | | | HCS02.1E-W0070 |
| 8299 | 183 | 9.6 | 5185 | 197 | 2.75 | 29 | 5185 | | | | HCS03.1E-W0070 |
| 10292 | 174 | 19.5 | 6700 | 190 | 4.59 | 24 | 7250 | | | | HCS03.1E-W0100 |
| 13617 | 158 | 43.9 | 6700 | 190 | 4.59 | 10 | 8491 | | | | HCS03.1E-W0150 |
| 17608 | 140 | 86 | 6700 | 190 | 4.59 | 5 | 10050 | | | | HCS03.1E-W0210 |
| 11694 | 136 | 12.9 | 4448 | 158 | 1.72 | 13 | 4448 | 28 | 140 | 300B-0070 | HMS01.1N-W0070 |
| 15678 | 123 | 31.9 | 7270 | 150 | 4.59 | 14 | 7270 | | | | HMS01.1N-W0110 |
| 19655 | 111 | 59.2 | 10300 | 140 | 9.21 | 16 | 11194 | | | | HMS01.1N-W0150 |
| 25631 | 92 | 116.1 | 10300 | 140 | 9.21 | 8 | 15178 | | | | HMS01.1N-W0210 |
| 11771 | 135 | 13.2 | 2562 | 164 | 0.57 | 4 | 2562 | | | | HCS02.1E-W0070 |
| 11694 | 136 | 12.9 | 6542 | 152 | 3.71 | 29 | 6542 | | | | HCS03.1E-W0070 |
| 14678 | 126 | 26.3 | 9975 | 141 | 8.64 | 33 | 9975 | | | | HCS03.1E-W0100 |
| 19655 | 111 | 59.2 | 10300 | 140 | 9.21 | 16 | 11982 | | | | HCS03.1E-W0150 |
| 25631 | 92 | 116.1 | 10300 | 140 | 9.21 | 8 | 15450 | | | | HCS03.1E-W0210 |
| 12925 | 182 | 15.3 | 5816 | 204 | 2.21 | 14 | 5816 | 35 | 205 | 300B-0120 | HMS01.1N-W0110 |
| 15546 | 174 | 28.5 | 9561 | 192 | 5.97 | 21 | 9561 | | | | HMS01.1N-W0150 |
| 19483 | 161 | 55.9 | 10300 | 190 | 6.93 | 12 | 12595 | | | | HMS01.1N-W0210 |
| 12267 | 184 | 12.7 | 7980 | 197 | 4.16 | 33 | 7980 | | | | HCS03.1E-W0100 |
| 15546 | 174 | 28.5 | 9905 | 191 | 6.93 | 22 | 10490 | | | | HCS03.1E-W0150 |
| 19483 | 161 | 55.9 | 10300 | 190 | 6.93 | 12 | 13273 | | | | HCS03.1E-W0210 |

Motor-Controller-Combinations

| $F_{MAX}$ [N] | $v_{Fmax}$ [m/min] | $P_{VMAX}$ [kW] | $F_{dN}$ [N] | $v_N$ [m/min] | $P_{vN}$ [kW] | $ED_{FMAX}$ [%] | $F_{KB}$ [N] | $I_{dN}$ [A] | $I_{MAX}$ [A] | Primary part Standard - / Thermal encapsulation MLP ... | Control device |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 15040 | 107 | 6.7 | 5605 | 123 | 0.89 | 13 | 5605 | 29 | 140 | 300C-0060 | HMS01.1N-W0070 |
| 20369 | 98 | 16.5 | 9162 | 117 | 2.38 | 14 | 9162 | | | | HMS01.1N-W0110 |
| 25688 | 89 | 30.7 | 13440 | 110 | 5.12 | 17 | 14372 | | | | HMS01.1N-W0150 |
| 33680 | 76 | 60.2 | 13440 | 110 | 5.12 | 9 | 19700 | | | | HMS01.1N-W0210 |
| 15144 | 107 | 6.8 | 3229 | 127 | 0.3 | 4 | 3229 | | | | HCS02.1E-W0070 |
| 15040 | 107 | 6.7 | 8244 | 119 | 1.93 | 29 | 8244 | | | | HCS03.1E-W0070 |
| 19032 | 101 | 13.6 | 12571 | 112 | 4.48 | 33 | 12571 | | | | HCS03.1E-W0100 |
| 25688 | 89 | 30.7 | 13440 | 110 | 5.12 | 17 | 15426 | | | | HCS03.1E-W0150 |
| 33680 | 76 | 60.2 | 13440 | 110 | 5.12 | 9 | 20160 | | | | HCS03.1E-W0210 |
| 16486 | 144 | 18.9 | 7183 | 163 | 2.72 | 14 | 7183 | 37 | 212 | 300C0090 | HMS01.1N-W0110 |
| 19860 | 137 | 35.1 | 11808 | 153 | 7.35 | 21 | 11808 | | | | HMS01.1N-W0150 |
| 24930 | 127 | 68.8 | 13440 | 150 | 9.52 | 14 | 16062 | | | | HMS01.1N-W0210 |
| 15638 | 146 | 15.6 | 9855 | 157 | 5.12 | 33 | 9855 | | | | HCS03.1E-W0100 |
| 19860 | 137 | 35.1 | 13247 | 150 | 9.25 | 26 | 13247 | | | | HCS03.1E-W0150 |
| 24930 | 127 | 68.8 | 13440 | 150 | 9.25 | 14 | 16933 | | | | HCS03.1E-W0210 |

*Fig.10-3: Possible combination at parallel arrangement*

# 11 Motor Dimensioning

## 11.1 General Procedure

The dimensioning of linear drives is mainly determined by the application-related characteristics of velocity and feed force. The basic sequence of sizing linear drives is shown in the figure below.

Motor Dimensioning

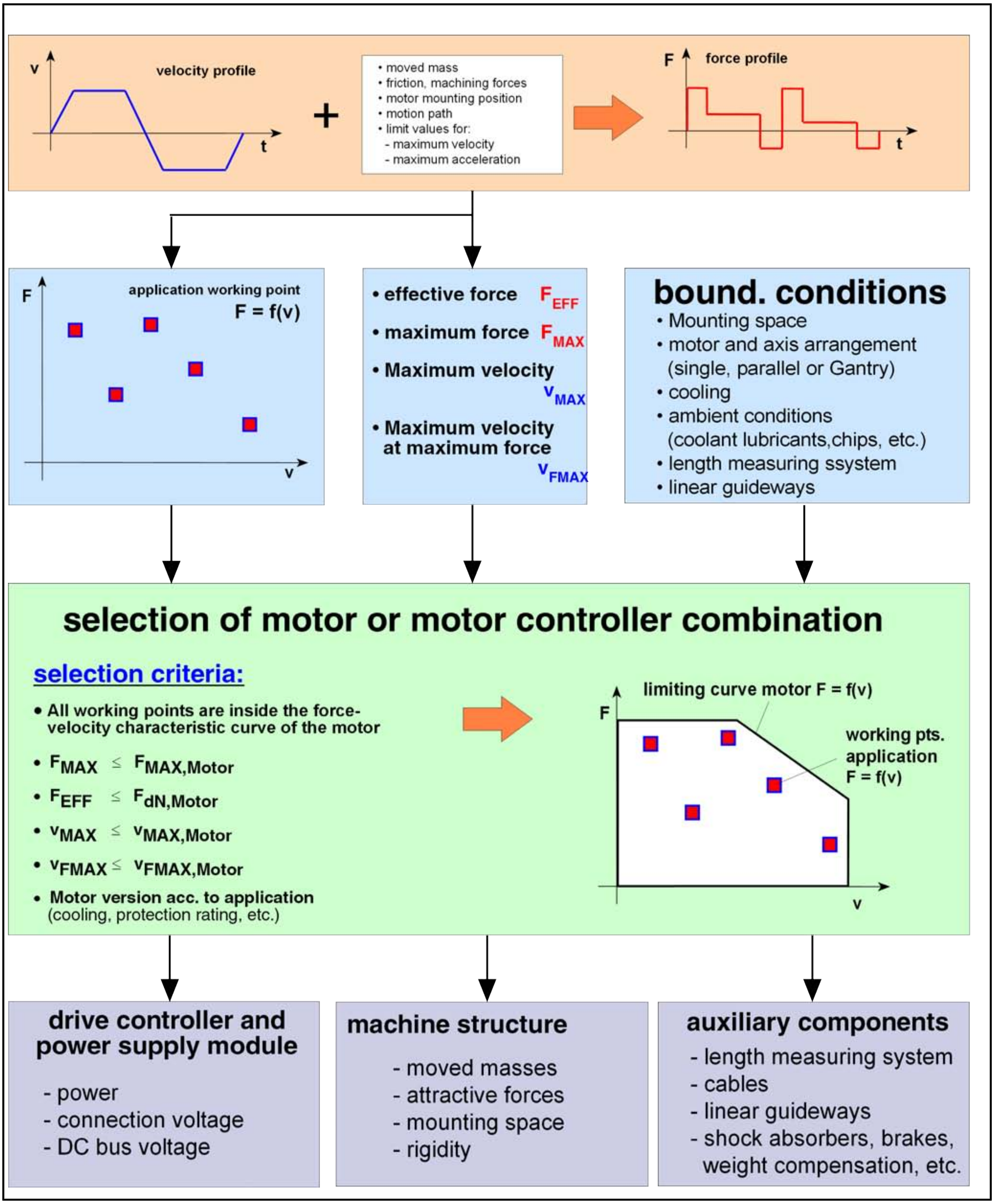



*Fig.11-1: Basic procedure of sizing linear drives*

# 11.2 Basic Formulae

## 11.2.1 General Movement Equations

The variables required for sizing and selecting the motor are calculated using the equations shown in the following.

☞ When linear direct drives are configured, the process-related feed forces and velocities are used directly and without conversion for selecting the drive.

Velocity $$v(t) = \frac{s(t)}{dt}$$

Acceleration: $$a(t) = \frac{v(t)}{dt}$$

Force: $$F(t) = a(t) \cdot m + F_0(t) + F_P(t)$$

Effective force: $$F_{eff} = \sqrt{\frac{1}{T} \cdot \int_0^T F(t)^2 dt}$$

Average velocity: $$v_{avg} = \frac{1}{T} \cdot \int_0^T v(t)\, dt$$

| | |
|---|---|
| v(t) | Velocity profile vs. time in m/s |
| s(t) | Path profile vs. time in m |
| a(t) | Acceleration profile vs. time in m/s² |
| F(t) | Force profile vs. time in N |
| m | Moved mass in kg |
| $F_0(t)$ | Base force in N |
| $F_P(t)$ | Process or machining force in N |
| $F_{eff}$ | Effective force in N |
| $v_{avg}$ | Average velocity in m/s |
| t | Time in s |
| T | Total time in s |

*Fig. 11-2: General equations of motion*

In most cases the mathematical description of the required positions vs. the time is known (NC-program, electronic cam disk). Using the preparatory function, velocity, acceleration and forces can be calculated. Standard software (such as MS Excel or MathCad) can be used for calculating the required variables, even with complex motion profiles.

☞ The following Chapter provides a more detailed correlation for trapezoidal, triangular or sinusoidal velocity characteristics.

## 11.2.2 Feed Forces

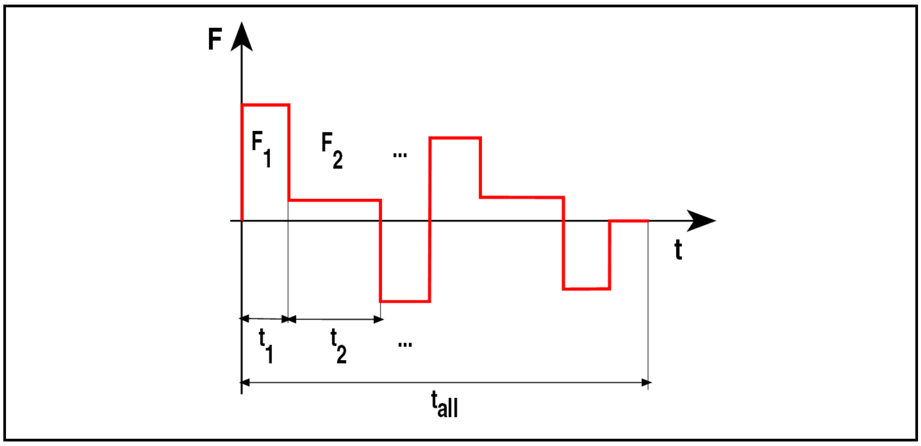



*Fig. 11-3: Determining the feed forces*

Acceleration force: $F_{ACC} = m \cdot a$

Force due to weight: $F_W = m \cdot g \cdot \sin\alpha \cdot (1 - \frac{f_{cb}}{100})$

Frictional force: $F_F = \mu \cdot (m \cdot g \cdot \sin\alpha + F_{ATT}) + F_0$

Maximum force: $F_{MAX} = F_{ACC} + F_F + F_W + F_P$

Effective force: $F_{EFF} = \sqrt{\frac{F_1^2 \cdot t_1 + F_2^2 \cdot t_2 + \ldots}{t_{all}}}$

| | |
|---|---|
| $F_{ACC}$ | Acceleration force in N |
| $F_W$ | Force due to weight in N |
| $F_F$ | Frictional force in N |
| $F_0$ | Additional frictional or base force in N (e.g. by seals of linear guides) |
| $F_{MAX}$ | Maximum force in N |
| $F_{EFF}$ | Effective force in N |
| $F_P$ | Processing force in N |
| a | Acceleration in m/s² |
| m | Moved mass in kg |
| g | Gravitational acceleration (9.81 m/s²) |
| α | Axis angel in degrees (0°: horizontal axis; 90°C: vertical axis |
| $f_{CB}$ | Weight compensation in % |
| $t_{all}$ | Total duty cycle time in s |
| $F_{ATT}$ | Attractive force between primary and secondary part in N |
| μ | Friction coefficient |

*Fig. 11-4: Determining the feed forces*

☞ For sizing calculations of linear motor drives, the moved mass of the motor component must be taken into account (in particular, if the slide masses are relatively small). However, the moved mass and the attractive force between primary and secondary part are only known after the motor has been selected. Thus, first make assumptions for these variables and verify these values after the motor has been selected.

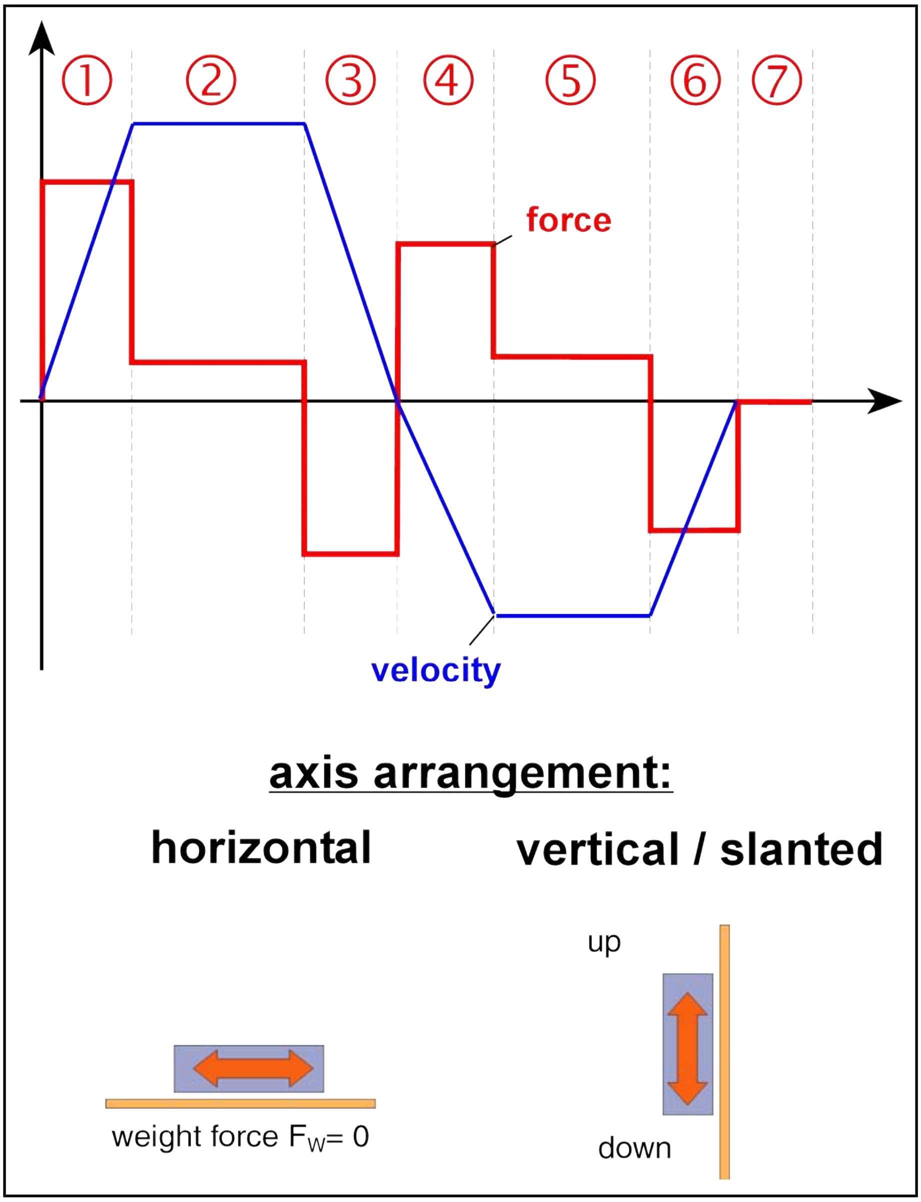



*Fig. 11-5: Determining the resulting feed forces according to motion type and direction*

| | | |
|---|---|---|
| (1) | Acceleration (up) : | $F = F_{ACC} + F_F + F_W$ |
| (2) | Const. velocity (up) : | $F = F_F + F_W$ |
| (3) | Deceleration (up) : | $F = -F_{ACC} + F_F + F_W$ |
| (4) | Acceleration (down) : | $F = F_{ACC} + F_F - F_W$ |
| (5) | Const. velocity (down) : | $F = F_F - F_W$ |
| (6) | Deceleration (down) : | $F = -F_{ACC} + F_F - F_W$ |
| (7) | Idle time: | $F = F_W$ |

$F_{ACC}$ Acceleration force in N
$F_W$ Force due to weight in N
$F_F$ Frictional force in N

*Fig. 11-6: Determining the resulting feed forces according to motion type and direction*

With horizontal axis arrangement, the weight is $F_W = 0$.

Further directional base and process forces must be taken into account.

## 11.2.3 Average Velocity

The average velocity is required for determining the mechanical continuous output of the drive. fig. 11-2 "General equations of motion" on page 181shows the general way of determining the average velocity. The following calculation can be used for a simple determination in trapezoidal or triangular velocity profiles:

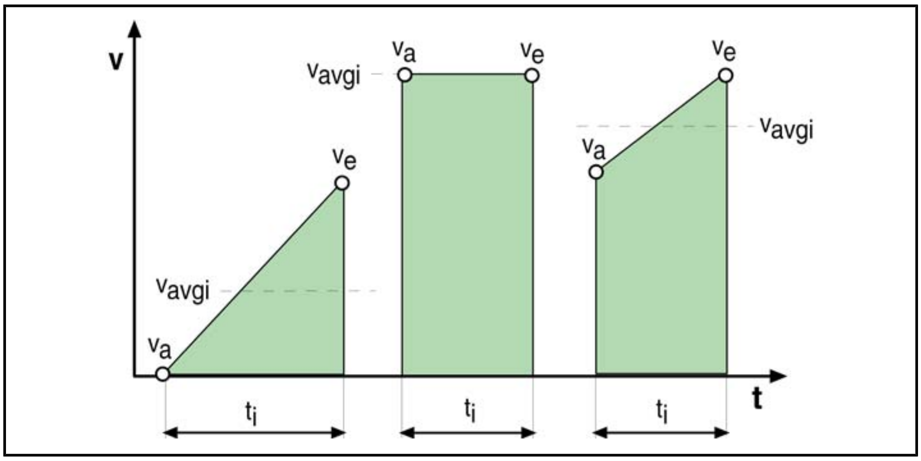



*Fig. 11-7: Triangular or trapezoidal velocity profile*

$$v_{avgi} = \frac{|v_a| - |v_e|}{2}$$

$$v_{avg} = \frac{\sum v_{avg\,i} \cdot t_i}{t_{all}}$$

| | |
|---|---|
| $v_{avgi}$ | Average velocity for a velocity segment of the duration ti in m/s |
| $v_a$ | Initial velocity of the velocity segment in m/s |
| $v_e$ | Final velocity of the velocity segment in m/s |
| $v_{avg}$ | Average velocity over total duty cycle time in m/s |
| $t_i$ | Duration of velocity segment in s |
| $t_{all}$ | Total duty cycle time, including breaks and/or standstill time, in s |

*Fig. 11-8: Determining the average velocity with triangular or trapezoidal velocity profile*

## 11.2.4 Trapezoidal Velocity

### General Information

This mode of operation is characteristic for the most applications. An acceleration phase is followed by a movement of constant velocity up to the deceleration phase.

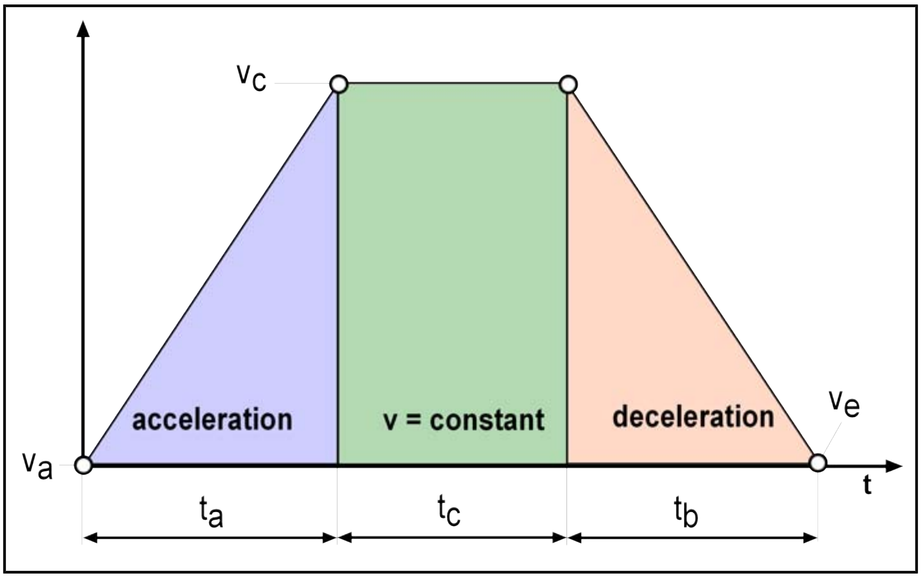



*Fig. 11-9: Trapezoidal velocity profile*

### Acceleration, initial velocity = 0

☞
- Velocity v ≠ constant
- Initial velocity $v_a = 0$
- Acceleration a = constant and positive

Acceleration: $$a = \frac{v_c}{t_a} = \frac{2 \cdot s}{t_a^2} = \frac{v_c^2}{2 \cdot s}$$

Final velocity: $$v_c = a \cdot t_a = \sqrt{2 \cdot a \cdot s} = \frac{2 \cdot s}{t_a}$$

Travel: $$s = \frac{v_c}{2} \cdot t_a = \frac{v_c^2}{2 \cdot a} = \frac{a \cdot t_a^2}{2}$$

Time: $$t_a = \frac{v_c}{a} = \frac{2 \cdot s}{v_c} = \sqrt{\frac{2 \cdot s}{a}}$$

| | |
|---|---|
| a | Acceleration in m/s² |
| $v_c$ | Final velocity in m/s |
| $t_a$ | Acceleration time in s |
| s | Travel covered during acceleration in m |

*Fig.11-10: Constantly accelerated movement, initial velocity = 0 (for trapezoidal velocity profile)*

## Acceleration, initial velocity ≠ 0

☞

- Velocity v ≠ constant
- Initial velocity $v_a$ ≠ 0
- Acceleration a = constant and positive

Acceleration: $$a = \frac{v_c - v_a}{t_a} = \frac{2 \cdot s}{t_a^2} - \frac{2 \cdot v_a}{t_a} = \frac{v_c^2 - v_a^2}{2 \cdot s}$$

Velocity: $$v_c = v_a + a \cdot t_a = \sqrt{2 \cdot a \cdot s + v_a^2} = \frac{2 \cdot s}{t_a} - v_a$$

Travel: $$s = \frac{v_c + v_a}{2} \cdot t_a = \frac{v_c^2 - v_a^2}{2 \cdot a} = v_a \cdot t_a + \frac{a \cdot t_a^2}{2}$$

Time: $$t_a = \frac{v_c - v_a}{a} = \frac{2 \cdot s}{v_c + v_a} = \frac{\sqrt{2 \cdot a \cdot s + v_a^2} - v_a}{a}$$

| | |
|---|---|
| $a$ | Acceleration in m/s² |
| $v_c$ | Final velocity in m/s |
| $v_a$ | Initial velocity in m/s |
| $t_a$ | Acceleration time in s |
| $s$ | Travel covered during acceleration in m |

*Fig. 11-11: Constantly accelerated movement, initial velocity ≠ 0 (for trapezoidal velocity profile)*

## Constant velocity

- Velocity v = constant
- Acceleration a = 0

Acceleration: $$v_c = \frac{s_c}{t_c}$$

Travel: $$s_c = v_c \cdot t_c$$

Time: $$t_c = \frac{s_c}{v_c}$$

| | |
|---|---|
| $v_c$ | Average velocity in m/s |
| $t_c$ | Time during constant velocity in s |
| $s_c$ | Travel covered constant velocity in m |

*Fig. 11-12: Constant velocity (for trapezoidal velocity profile)*

## Brakes, Final Velocity = 0

- Velocity v ≠ constant
- Final velocity $v_e$ = 0
- Acceleration a = constant and negative

Motor Dimensioning

| | |
|---|---|
| Acceleration: | $a = \frac{v_c}{t_b} = \frac{2 \cdot s}{t_b^2} = \frac{v_c^2}{2 \cdot s}$ |
| Velocity: | $v_c = a \cdot t_b = \sqrt{2 \cdot a \cdot s} = \frac{2 \cdot s}{t_b}$ |
| Travel: | $s = \frac{v_c}{2} \cdot t_b = \frac{v_c^2}{2 \cdot a} = \frac{a \cdot t_b^2}{2}$ |
| Time: | $t_b = \frac{v_c}{a} = \frac{2 \cdot s}{v_c} = \sqrt{\frac{2 \cdot s}{a}}$ |

| | |
|---|---|
| a | Acceleration in m/s² |
| $v_c$ | Final velocity in m/s |
| $t_b$ | Deceleration time in s |
| s | Travel covered during acceleration in m |

*Fig. 11-13: Constantly accelerated movement, initial velocity = 0 (for trapezoidal velocity profile)*

## Brakes, Final Velocity ≠ 0

☞
- Velocity v ≠ constant
- Final velocity $v_e \neq 0$
- Acceleration a = constant and negative

Acceleration: $$a = \frac{v_c - v_e}{t_b} = \frac{2 \cdot v_c}{t_b} - \frac{2 \cdot s}{t_b^2} = \frac{v_c^2 - v_e^2}{2 \cdot s}$$

Velocity: $$v_e = v_c - a \cdot t_b = \sqrt{v_c^2 - 2 \cdot a \cdot s} = \frac{2 \cdot s}{t_b} - v_c$$

Travel: $$s = \frac{v_c + v_e}{2} \cdot t_b = \frac{v_c^2 - v_e^2}{2 \cdot a} = v_c \cdot t_b + \frac{a \cdot t_b^2}{2}$$

Time : $$t_a = \frac{v_c - v_e}{a} = \frac{2 \cdot s}{v_c + v_e} = \frac{v_c - \sqrt{v_c^2 - 2 \cdot a \cdot s}}{a}$$

| | |
|---|---|
| $a$ | Acceleration in m/s² |
| $v_c$ | Initial velocity in m/s |
| $v_e$ | Final velocity in m/s |
| $t_b$ | Deceleration time in s |
| $s$ | Travel covered during acceleration in m |

*Fig. 11-14: Constantly accelerated movement, initial velocity ≠ 0 (for trapezoidal velocity profile)*

## 11.2.5 Triangular Velocity

In contrast to the trapezoidal characteristic, this velocity profile does not have a phase of constant velocity. The acceleration phase is immediately followed by the deceleration phase. This characteristic can frequently be found in conjunction with movements of short strokes.

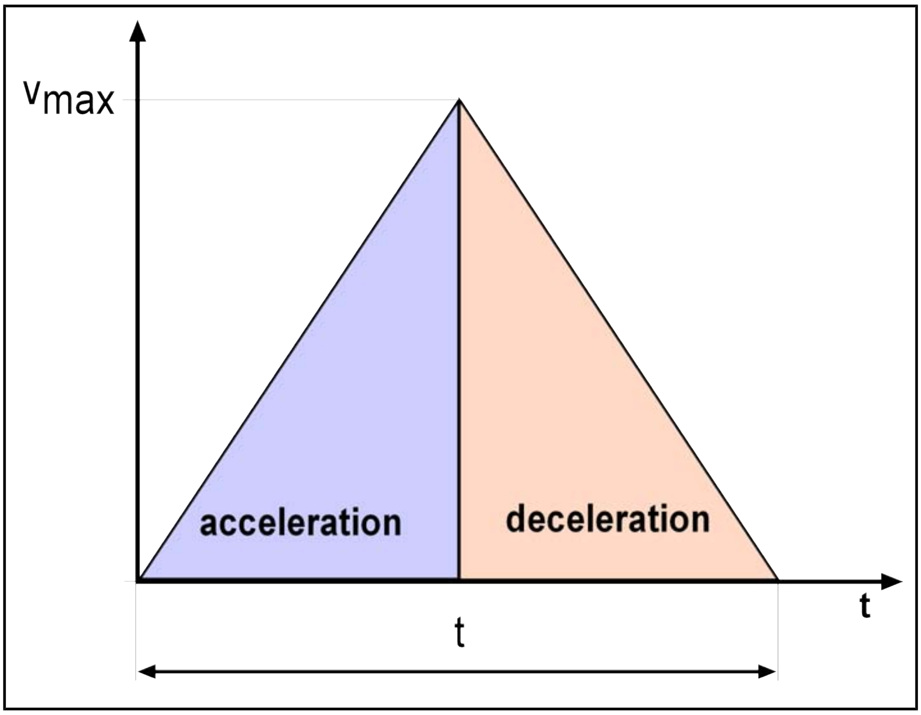



*Fig. 11-15: Triangular velocity profile*

Acceleration: $$a = \frac{2 \cdot v_{max}}{t} = \frac{4 \cdot s_{all}}{t^2} = \frac{v_{max}^2}{s}$$

Velocity: $$v_{max} = \frac{a \cdot t}{2} = \sqrt{a \cdot s_{all}} = \frac{2 \cdot s_{all}}{t}$$

Travel: $$s_{all} = \frac{v_{max} \cdot t}{2} = \frac{v_{max}^2}{4 \cdot a} = \frac{a \cdot t^2}{4}$$

Time: $$t = \frac{2 \cdot v_{max}}{a} = \frac{4 \cdot s_{all}}{v_{max}} = \sqrt{\frac{4 \cdot s_{all}}{a}}$$

| | |
|---|---|
| $v_{max}$ | Maximum velocity in m/s |
| a | Acceleration in m/s² |
| $s_{all}$ | Total motion travel in m |
| t | Positioning time in s |

*Fig. 11-16: Determine triangular velocity profile*

## 11.2.6 Sinusoidal Velocity

This velocity profile results, for example, from the circular interplation of two axes (circular movement) or the oscillating movement of one axis (grinding, for example).

The specified variables are chiefly the motion travel or the circle diameter and the period T.

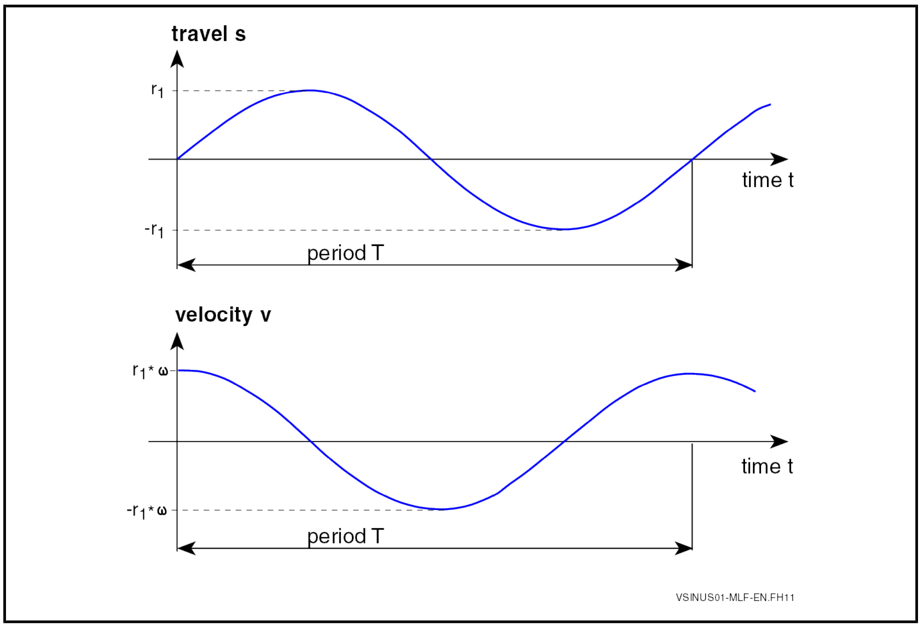



*Fig. 11-17: Insert motion profiles of an axis at sinusoidal velocity.*

Travel profile: $s(t) = r_1 \cdot \sin(\omega \cdot t)$

Velocity profile: $v(t) = r_1 \cdot \cos(\omega \cdot t) \cdot \omega$

Acceleration profile: $a(t) = -r_1 \cdot \sin(\omega t) \cdot \omega^2$

Jerk profile: $r(t) = -r_1 \cdot \cos(\omega t) \cdot \omega^3$

$$\omega = \frac{2 \cdot \pi}{T} = 2 \cdot \pi \cdot f$$

*Fig. 11-18: Calculation formula for motion profiles of an axis at sinusoidal velocity.*

The following calculation bases on fig. 11-17 "Insert motion profiles of an axis at sinusoidal velocity." on page 190 and fig. 11-18 "Calculation formula for motion profiles of an axis at sinusoidal velocity." on page 191:

Maximum accerlation: $a_{max} = r \cdot \left(\frac{2 \cdot \pi}{T}\right)^2$

Maximum velocity: $v_{max} = r \cdot \frac{2 \cdot \pi}{T}$

Average velocity: $v_{avg} = \frac{2 \cdot v_{max}}{\pi} = \frac{4 \cdot r}{T}$

Acceleration force: $F_{ACC} = a_{max} \cdot m$

Effective force: $F_{EFF} = \sqrt{\frac{{F_{acc}}^2}{2} + F_0^2}$

Vertical axis arrangement:

$$F_{EFFv} = \sqrt{\frac{F_{acc}^2 + F_{0\,up}^2 + F_{0\,down}^2}{2}}$$

Base force up movement: $F_{0\,up} = F_0 + F_w$

Base force down movement: $F_{0\,down} = F_0 - F_w$

| | |
|---|---|
| $a_{max}$ | Maximum acceleration in m/s² |
| $v_{max}$ | Maximum velocity in m/s |
| r | Motion travel in one direction (or circle radius) in m |
| T | Period in s |
| m | Moved mass in kg |
| $F_{ACC}$ | Acceleration force in N |
| $F_{EFF}$ | Effective force in N |
| $F_{EFFv}$ | Effektive force at vertical or inclined axis arrangement in N |
| $F_0$ | Base force, e.g. frictional force in N |
| $F_W$ | Force due to weight in N |

*Fig. 11-19: Calculation formulae for sinusoidal velocity profile*

☞ Further directional base and process forces must additionally be taken into account.

# 11.3 Duty Cycle and Feed Force

## 11.3.1 General Information

The relative duty cycle ED specifies the duty cycle percentage of the load with respect to a total duty cycle time, including idle time. The thermal load capacity of the motor limits the duty cycle. Capacity the motor with rated force is possible over the entire duty cycle time. The duty cycle must be reduced at $F > F_{dN}$ (see fig. 11-20 "Correlation between duty cycle and feed force" on page 193) in order to not thermally overload the motor at higher feed forces.

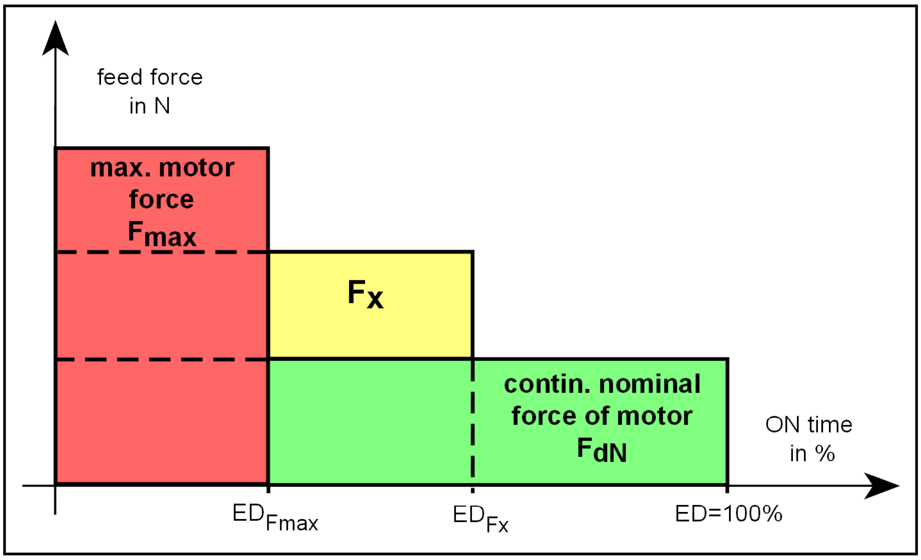



*Fig. 11-20: Correlation between duty cycle and feed force*

## 11.3.2 Determining the Duty Cycle

The approximate determination of the relative duty cycle $ED_{ideal}$ is performed via the correlation:

$$ED_{ideal} = \left( \frac{F_{EFF}^2}{F_{MAX}^2} \right) \cdot 100$$

| | |
|---|---|
| $ED_{ideal}$ | Cyclic duration factor in % |
| $F_{EFF}$ | Effective force or rated force in N |
| $F_{MAX}$ | Maximum feed force |

*Fig. 11-21: Approximate determination of duty cycle ED*

**Prerequisites:** Linear correlation between feed force and current.

For IndraDyn L motors acc. to fig. 11-21 "Approximate determination of duty cycle ED" on page 193, only an approximate duty cycle calculation is possible since there is a non-linear correlation between force and current.

This calculation is valid for a rough determination of possible duty cycle at short-time duty forces with $F_{KB} \leq 1.5\ F_{dN}$.

☞ You must check with fig. 11-22 "Determining the duty cycle ED" on page 194 or fig. 11-23 "Duty cycle vs. force for IndraDyn L synchronous linear motors" on page 194 to exactly determine the relative duty cycle of IndraDyn L linear motors.

The non-linearity of the characteristic curve force vs. current of synchronous linear motor leads to an increased rise of power loss at higher feed forces. This increased power loss leads – in particular at a high percentage of acceleration and deceleration processes – to a possible duty cycle that is reduced with respect to fig. 11-21 "Approximate determination of duty cycle ED" on page 193.

Use fig. 11-22 "Determining the duty cycle ED" on page 194 or fig. 11-23 "Duty cycle vs. force for IndraDyn L synchronous linear motors" on page 194 to determine exactly the possible relative duty cycle.

$$ED_{real} = \frac{P_{vN}}{P_{AVG\,a}} \cdot 100$$

| | |
|---|---|
| $ED_{real}$ | Possible relative duty cycle in % |
| $P_{vN}$ | Maximum rated power loss of the motor in W (see Chapter 4 ”Technical data”) |
| $P_{AVG\,a}$ | Average motor power loss in application over a duty cycle time including idle time in W |

*Fig. 11-22: Determining the duty cycle ED*

**Prerequisites:** Duty cycle time ≤ Thermal time constant of motor

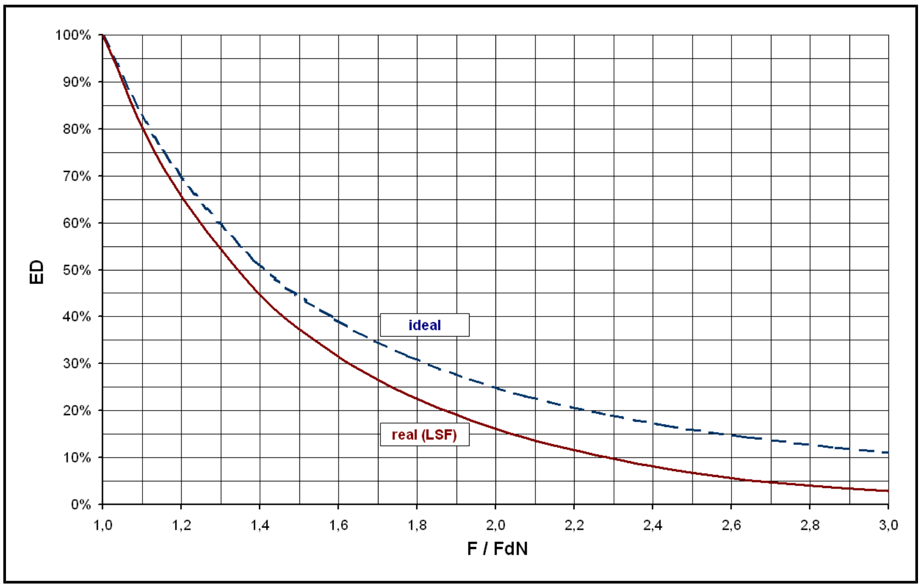



*Fig. 11-23: Duty cycle vs. force for IndraDyn L synchronous linear motors*

# 11.4 Determining the Drive Power

## 11.4.1 General Information

To size the power supply module or the mains rating, you must determine the rated (continuous) and maximum power of the linear drive.

☞ Take the corresponding simultaneity factor into account when determine the total power of several drives that are connected to a single power supply module.

## 11.4.2 Rated Output

The rated output corresponds to the sum of the mechanical and electrical motor power.

Total rated output: $P_c = P_{cm} + P_{ce}$

Mechanical rated output: $P_{cm} = F_{eff} \cdot v_{avg}$

Rated electrical output: $P_{ce} = \left(\frac{F_{eff}}{F_{dn}}\right)^2 \cdot P_{vn}$ with $F_{eff} \leq F_{dn}$

| | |
|---|---|
| $P_c$ | Rated power in W |
| $P_{cm}$ | Mechanical rated output in W |
| $P_{ce}$ | Electrical rated power loss of motor in W |
| $F_{eff}$ | Effective force in N (from application) |
| $v_{avg}$ | Average velocity in m/s |
| $F_{dn}$ | Rated force of the motor in N (see Chapter 4 ”Technical data”) |
| $P_{vn}$ | Rated power loss of the motor in W (see Chapter 4 ”Technical data”) |

*Fig. 11-24: Rated power of the linear motor*

The rated electrical output (see fig. 11-24 "Rated power of the linear motor" on page 195) is reduced when the rated force is reduced.

## 11.4.3 Maximum Output

The maximum output is also the sum of the mechanical and electrical maximum output. It must be made available to the drive during acceleration and deceleration phase or for very high machining forces, for example.

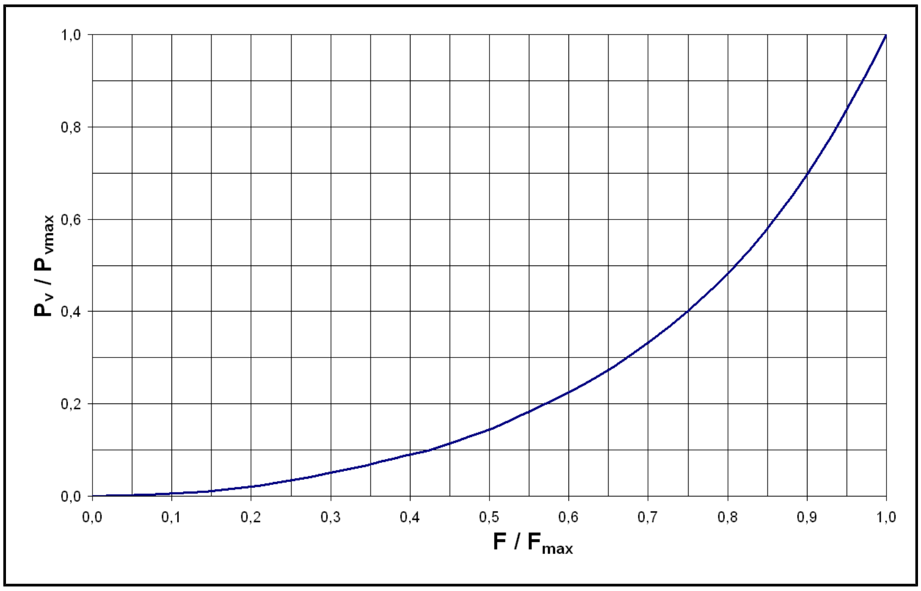
Total maximum power: $P_{max} = P_{maxm} + P_{maxe}$

Mechanical maximum power: $P_{maxm} = F_{max} \cdot v_{Fmax}$

| | |
|---|---|
| $P_{max}$ | Total maximum power in W |
| $P_{maxm}$ | Mechanical maximum power in W |
| $P_{maxe}$ | Electrical maximum power in W (see the following diagram) |
| $F_{max}$ | Maximum feed force in N |
| $v_{Fmax}$ | Maximum velocity with Fmax in N |

*Fig. 11-25: Maximum power of the linear motor*

When the maximum feed force is reduced against the achievable maximum force of the motor, the electrical maximum output $P_{maxe}$ is reduced, too. To determine the reduced electrical maximum output $P_{maxe}$ use fig. 11-26 "Diagram used for determining the reduced electrical power loss" on page 196.




| | |
|---|---|
| $F_{max}$ | Maximum force of the motor in N |
| F | Maximum force application in N |
| $P_{vmax}$ | Maximum power loss of the motor in W |
| $P_v$ | Power loss of the motor application in W |

*Fig. 11-26: Diagram used for determining the reduced electrical power loss*

☞ The maximum power loss is specified in Chapter 10 ”Motor-Controller-Combination”.

## 11.4.4 Cooling Capacity

The necessary cooling capacity nearly corresponds to the motor´s electrical continuous power loss.

$$\text{Required cooling capacity:}\quad P_{co} = P_{ce} = \left(\frac{F_{eff}}{F_{dn}}\right)^2 \cdot P_{vn} \quad \text{with } F_{eff} \leq F_{dn}$$

| | |
|---|---|
| $P_{co}$ | Required cooling capacity in W |
| $P_{ce}$ | Electrical power loss of motor in W |
| $F_{eff}$ | Effective force in N |
| $F_{dn}$ | Rated force of the motor in N (see Chapter 4 ”Technical data”) |
| $P_{vn}$ | Rated power loss of the motor in W (see Chapter 4 ”Technical data”) |

*Fig. 11-27: Required cooling capacity of the linear motor*

## 11.4.5 Energy Regeneration

Compared with rotary servo motors, the energy of a linear motor during deceleration is lower. The translatory velocity of a linear motor is usually much lower than the circumferential speed of a rotary servo motor.

The regeneration energy of a synchronous linear drive results from the energy balance during the deceleration process. To size additional brake resistors or power supply units with feedback capability, it can be estimated as follows.

$$P_R = \frac{m \cdot v^2}{2 \cdot t_b} - \frac{v \cdot F_R}{2} - 1{,}5 \cdot m^2 \cdot R_{12} \cdot \left(\frac{a_{max}}{k_{iFN}}\right)^2$$

$$P_{Ravg} = \frac{1}{T} \cdot \int_0^T P_R(t)\ dt = \frac{\sum P_{R\,i} \cdot t_{bi}}{t_{all}}$$

| | |
|---|---|
| $P_R$ | Regeneration energy during a deceleration phase in W |
| $P_{Ravg}$ | Average regeneration energy over total duty cycle time in W |
| m | Moved mass in kg |
| v | Maximum velocity in m/s |
| $t_b$ | Deceleration time in s |
| $F_R$ | Frictional force in N |
| $R_{12}$ | Winding resistance of the motor at 20°C in Ohm (see Chapter 4 Technical Data) |
| $a_{max}$ | Braking deceleration (negative acceleration) in m/s² |
| $k_{iFN}$ | Motor constant in N/A |
| $t_{all}$ | Total duty cycle time in s |

*Fig. 11-28: Regeneration energy of the linear motor*

**Prerequisites:** Velocity-independent friction

Constant deceleration

Final velocity = 0

☞ If the regeneration energy that is determined according to fig. 11-28 "Regeneration energy of the linear motor" on page 197 is negative, energy is not fed back. This means that energy must be supplied to the motor during the deceleration process.

## 11.5 Efficiency

The efficiency of electrical machines is the ration between the motor output and the power fed to the motor. With linear motors, it is determined by the application-related traverse rates and forces, and the corresponding motor losses.

fig. 11-29 "Determining the efficiency of linear motors" on page 197 and fig. 11-30 "Efficiency vs. velocity for IndraDyn L synchronous linear motors." on page 198 can be used for determining and/or estimating the motor efficiency.

$$\eta = \frac{P_{mech}}{P_{mech} + P_{V\,el}} = \frac{F \cdot v}{(F \cdot v) + P_{V\,el}} = \frac{1}{1 + \frac{P_{Vel}}{F \cdot v}}$$

| | |
|---|---|
| η | Efficiency |
| $P_{mech}$ | Mechanical output in W |
| $P_{Vel}$ | Electrical power loss in W |
| F | Feed force in N |
| v | Velocity in m/s |

*Fig. 11-29: Determining the efficiency of linear motors*

Motor Dimensioning

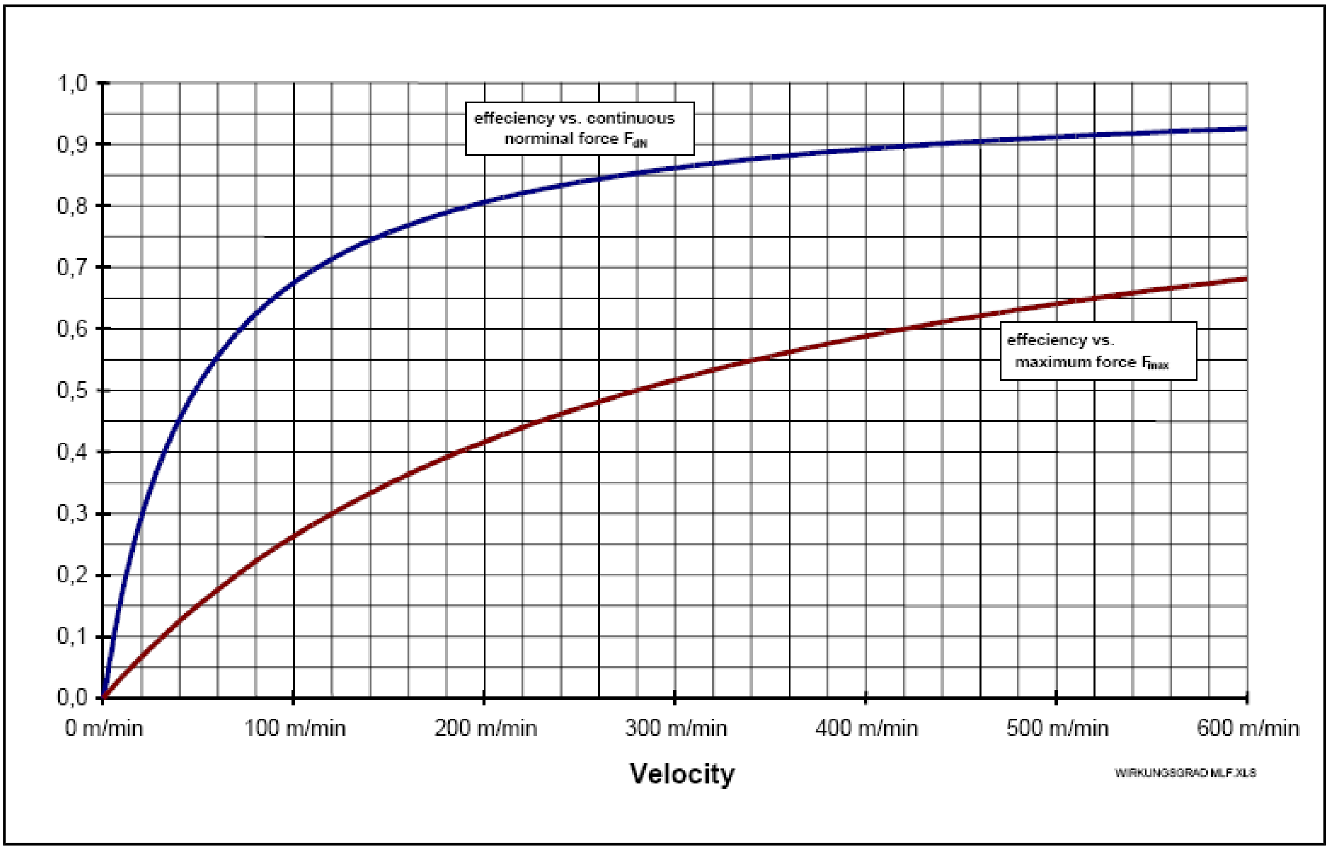



*Fig.11-30: Efficiency vs. velocity for IndraDyn L synchronous linear motors.*

# 11.6 Sizing Examples

## 11.6.1 Handling axis

### General Information

The example of a simple handling axis is used for describing the basic procedure of sizing a linear drive.

### Specifications

The following data is specified:

Slide mass: $m_S$= 52 kg

Maximum velocity possible: 300 m/min

Maximum acceleration possible: 50 m/s²

Axis arrangement: horizontally, primary part moved

Base force through energy chain,
seals, linear guides, etc.: $F_{zus}$ = 150 N (constant)

Additional process forces: none

Friction coefficient of linear guides: μ = 0.005

Rated connecting voltage: 3 x AC 400V

Coolant temperature (water): $\vartheta_{coolant}$ = 25 °C

Required positioning movements:

| No.: | Stroke | Positioning time | Idle time after stroke | Comment |
|---|---|---|---|---|
| 1 | 600 mm | 0.32 s | 0.20 s | Moving from start position to part pickup |
| 2 | -1,300 mm | 0.50 s | 0.20 s | Parts transport and deposit |
| 3 | 700 mm | 0.35 s | 0.45 s | Moving back to start position |

*Fig. 11-31: Required positioning movements of the handling axis*

The mass of the primary part must be taken into account when the feed forces are determined. The attractive force between primary and secondary part is required additionally when the frictional force is determined. The following assumptions are made to start with:

Primary part mass: $m_P$= 32 kg

Attractive force: $F_{ATT}$ = 8,000 N

Check the calculations again when you have selected the motor.

## Calculation

The following velocity and acceleration values are selected in order to maintain the required position times and specified limitations.

| No.: | Stroke | Positioning time | Feed rate | Acceleration |
|---|---|---|---|---|
| 1 | 600 mm | 0.32 s | 180 m/min | 25 m/s² |
| 2 | -1,300 mm | 0.50 s | 220 m/min | 25 m/s² |
| 3 | 700 mm | 0.35 s | 185 m/min | 25 m/s² |

*Fig. 11-32: Selected velocities and accelerations of the handling axes*

☞ When you select the position velocity and positioning acceleration, you should try to find an optimum ration for the motor selection (to reach a minimum effective force, for example).

$$m_{ges} = m_S + m_P$$
$$m_{ges} = 52\ \text{kg} + 32\ \text{kg}$$
$$m_{ges} = 84\ \text{kg}$$

*Fig. 11-33: Moved total mass*

$$F_0 = F_F + F_{zus}$$
$$F_0 = \mu \cdot (m_{ges} \cdot g + F_{ATT}) + F_{zus}$$
$$F_0 = 0.005 \cdot (84\,kg \cdot 9.81\,m/s^2 + 8000\,N) + 150\,N$$
$$F_0 = 194\,N$$

*Fig.11-34: Base force*

$$F_W = 0\,N$$

*Fig.11-35: Force due to weight*

$$F_{acc} = m_{ges} \cdot a_p$$
$$F_{acc} = (84\,kg) \cdot 25\,m/s^2$$
$$F_{acc} = 2100\,N$$

*Fig.11-36: Acceleration force*

$$F_{max} = F_{acc} + F_0$$
$$F_{max} = 2100\,N + 194N$$
$$F_{max} = 2294\,N$$

*Fig.11-37: Maximum force*

$$t_{ges} = 0.32\,s + 0.2\,s + 0.5\,s + 0.2\,s + 0.35\,s + 0.45\,s$$
$$t_{ges} = 2.02\,s$$

*Fig.11-38: Total time or duty cycle time*

**Velocity and Force Profile**

The selected velocities and the determined forces provide the following velocity and force profile:

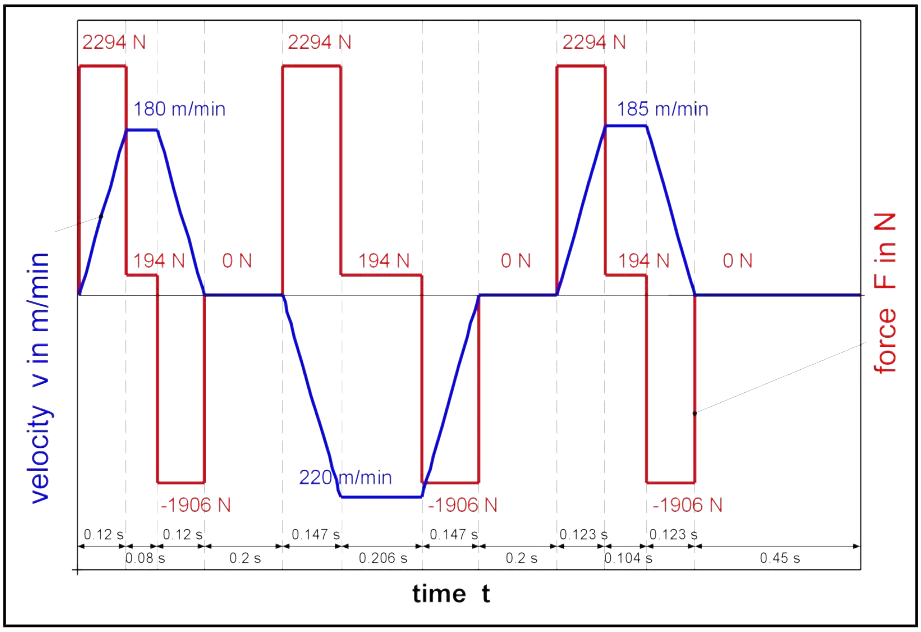



*Fig. 11-39: Velocity and force profile of handling axis*

**Effective Force and Average Velocity**

The effective force and the average velocity are determined on the basis of the force profile:

| No.: | Time $t_i$ in s | Force $F_i$ in N | | Average velocity $v_{avg\ i}$ in m/min |
|---|---|---|---|---|
| 1 | 0.120 | 2,294 | $F_i = F_{acc}+F_0$ | 90 |
| 2 | 0.080 | 194 | $F_i = F_0$ | 180 |
| 3 | 0.120 | -1,906 | $F_i = -F_{acc}+F_0$ | 90 |
| 4 | 0.200 | 0 | | 0 |
| 5 | 0.147 | 2,294 | $F_i = F_{acc}+F_0$ | 110 |
| 6 | 0.206 | 194 | $F_i = F_0$ | 220 |
| 7 | 0.147 | -1,906 | $F_i = -F_{acc}+F_0$ | 110 |
| 8 | 0.2 | 0 | | 0 |
| 9 | 0.123 | 2,294 | $F_i = F_{acc}+F_0$ | 92.5 |
| 10 | 0.104 | 194 | $F_i = F_0$ | 185 |
| 11 | 0.123 | -1,906 | $F_i = -F_{acc}+F_0$ | 92.5 |
| 12 | 0.45 | 0 N | | 0 |

*Fig. 11-40: Force profile vs. time to determine the effective force*

$$F_{eff} = \sqrt{\frac{\sum (F_i^2 \cdot t_i)}{t_{ges}}} \qquad v_{avg} = \frac{\sum v_{avgi} \cdot t_i}{t_{ges}}$$

$$F_{eff} = 1313N \qquad v_{avg} = 77.1m/min$$

*Fig.11-41: Determine the effective force and average velocity*

## Selection of motor – controller combination

Once the application data has been calculated, an appropriate motor-controller combination can be selected.

The standard encapsulation and the IndraDrive controller family are selected. Using the calculated data, the following combination is chosen from the selection data for motor-controller combinations (see Chapter 10):

**Motor:** MLP140C-0170-FS-xxxx

**Drive device:** HMS01.1N-W150

**Verification of Mass and Attractive Force**

The mass of the selected primary part MLP140C-0170-FS is slightly smaller than the previous mass. The same applies to the attractive force. The selected motor is retained within the scope of this example.

**Operation Points and Characteristic Curve of the Motor**

Using the profiles of velocity and force fig. 11-39 "Velocity and force profile of handling axis" on page 201), the operating points of the required feed forces and the necessary velocities can be determined. These operating points and the characteristics are shown in the Figure below.

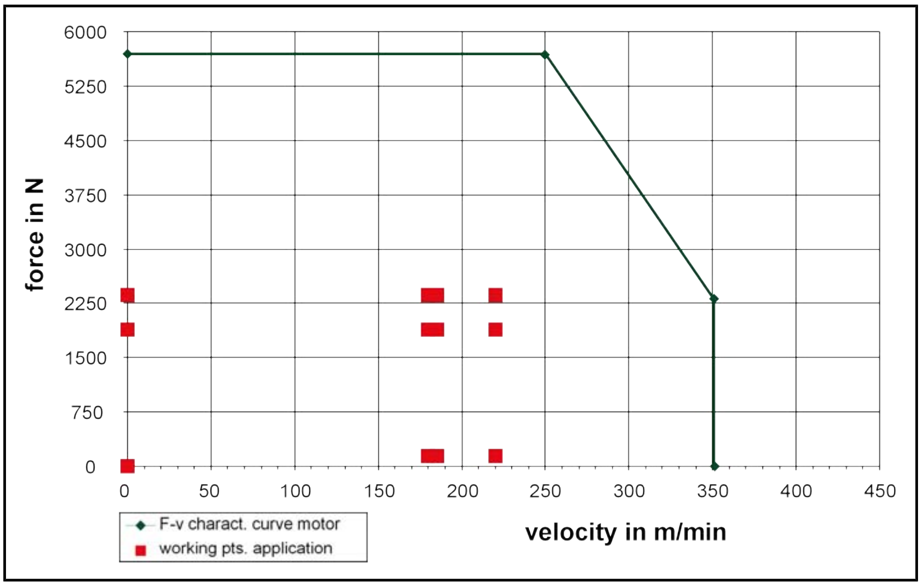



*Fig.11-42: Force-velocity diagram of handling axis (operating points and motor characteristic)*

All operating points that are related to force and velocity of the application must be inside the characteristic curve of the selected motor – controller combination.

## Selecting the secondary part segments

Based on the motion profile, the effective total motion path and, consequently, the required quantity and/or length of the secondary part segments can be determined. The effective total travel is 1300 mm; the length of the selected primary part is 510 mm.

$$L_{secondary} \geq L_{total\ travel} + L_{primary}$$
$$L_{secondary} = 1300\ mm + 510\ mm$$
$$L_{secondary} = 1810\ mm$$

*Fig. 11-43: Required length of the secondary parts*

**Selecting the secondary part segments**

Secondary part segments for IndraDyn L synchronous linear motors are available in a length of 150 mm, 450 mm and 600 mm.

Three secondary part segments of 600 mm each (total length of 1800 mm) are selected for the handling axes.

## Power Calculation

$$P_{cm} = F_{eff} \cdot v_{avg}$$
$$P_{cm} = 1313\ N \cdot \frac{77.1\ m/min}{60}$$
$$P_{cm} = 1687\ W$$

*Fig. 11-44: Rated mechanical power*

$$P_{ce} = \left(\frac{F_{eff}}{F_{n\_motor}}\right)^2 \cdot P_{vN}$$
$$P_{ce} = \left(\frac{1313\ N}{1785\ N}\right)^2 \cdot 1300\ W$$
$$P_{ce} = 703\ W$$

*Fig. 11-45: Rated electrical power loss*

$$P_c = P_{cm} + P_{ce}$$
$$P_c = 1687\ W + 703\ W$$
$$P_c = 2390\ W$$

*Fig. 11-46: Total rated power*

$$P_{maxm} = F_{max} \cdot v_{Fmax}$$
$$P_{maxm} = 2294\ N \cdot \frac{220\ m/min}{60}$$
$$P_{maxm} = 8412W$$

*Fig.11-47:* *Maximum output mechanical*

fig. 11-26 "Diagram used for determining the reduced electrical power loss" on page 196 is used for determining the maximum electrical power loss. The ratio of required maximum force and maximum force of the motor is 2294 N / 5600 N = 0.41.

Thus, fig. 11-26 "Diagram used for determining the reduced electrical power loss" on page 196shows a reduction factor of 0.095 for the maximum power loss. Together with the specification of the maximum motor power loss from the selection charts for the motor-controller combination, the maximum electrical power loss results as

$$P_{maxe} = 0.095 \cdot P_{max\ motor}$$
$$P_{maxe} = 0.095 \cdot 60.84\ kW$$
$$P_{maxe} = 5.78\ kW$$

*Fig.11-48:* *Maximum output electrical*

$$P_{max} = P_{maxm} + P_{maxe}$$
$$P_{max} = 8.41\ kW + 5.78\ kW$$
$$P_{max} = 14.19\ kW$$

*Fig.11-49:* *Total maximum output*

$$P_{co} = P_{ce} = 704\ W$$

*Fig.11-50:* *Cooling capacity*

fig. 11-28 "Regeneration energy of the linear motor" on page 197 and the motor data in Chapter 4 "Technical data" are used for determining the regeneration energy for all deceleration phases.

$$P_{Ri} = \frac{m \cdot v^2}{2 \cdot t_{bi}} - \frac{v \cdot F_R}{2} - 1{,}5 \cdot m^2 \cdot R_{12} \cdot \left(\frac{a_{max}}{k_{iFN}}\right)^2$$

*Fig.11-51:* *Regeneration energy*

| No.: | Braking time $t_{bi}$ | Feed rate | Acceleration | Energy regeneration $P_{Ri}$ |
|---|---|---|---|---|
| 1 | 0.120 s | 180 m/min | - 25 m/s² | 1,678 W |
| 2 | 0.147 s | 220 m/min | - 25 m/s² | 2,305 W |
| 3 | 0.123 s | 185 m/min | -25 m/s² | 1,767 W |

*Fig. 11-52: Regeneration energy during the deceleration phases*

The average regeneration energy over the entire duty cycle time amounts to:

$$P_{Ravg} = \frac{\sum P_{Ri} \cdot t_{bi}}{t_{all}}$$

$$P_{Ravg} = 375\ \text{W}$$

*Fig. 11-53: Average energy regeneration*

**Additional Capacities for Deactivation the Axis upon a Power Failure**

Additional DC bus capacities (condensers) shall ensure that the axis is safely deactivate in the event of a power failure. The determination of the necessary additional capacity in the DC must be done according to the following example. The motor brakes with with maximum feed force, the minimum DC bus voltage should be 50V. The maximum velocity is 220 m/min is considered as worst case.

$$C_{add} = \frac{m_{ges} \cdot v_{max}}{U_{DCmax}^2 - U_{DCmin}^2} \cdot \left[ 3{,}5 \cdot \frac{F_{max\_motor}}{k_{iF}^2} \cdot R_{12} - v_{max} \cdot \left( \frac{F_R}{F_{max\_motor}} + 0.3 \right) \right]$$

$$C_{add} = \frac{84\ \text{kg} \cdot 4.17 \frac{\text{m}}{\text{s}}}{(540\ \text{V})^2 - (50\ \text{V})^2} \cdot \left[ 3{,}5 \cdot \frac{5600\ \text{N}}{\left(82 \frac{\text{N}}{\text{A}}\right)^2} \cdot 1.2\ \Omega - 4.17 \frac{\text{m}}{\text{s}} \cdot \left( \frac{194\ \text{N}}{5600\ \text{N}} + 0.3 \right) \right]$$

$$C_{add} = 0.00242\ \text{F} = 2.4\ \text{mF}$$

*Fig. 11-54: Determine the additional capacity*

☞ The maximum possible DC bus capacity of the employed power supply module must be taken into account when additional capacities are used in the DC bus.

## Selection of linear scale

The linear scale can be selected when the effective total travel is known.

An open incremental linear scale of the LIDA187C type is selected for the handling axis. The selected system has distance-encoded reference marks.

## Motor efficiency

The motor efficiency, related on the continuous output, results as follows:

$$\eta_c = \frac{P_{cm}}{P_{cm} + P_{ce}} = \frac{1687\ W}{1687\ W + 703\ W}$$

$$\eta_c = 0.706$$

*Fig. 11-55: Motor efficiency*

## Final overtemperature of the motor

**Limit Overtemperature of the Motor Winding**

$$\vartheta_{wg} = \vartheta_{wmax} - \vartheta_{coolant}$$
$$\vartheta_{wg} = 155\ K - 25\ K$$
$$\vartheta_{wg} = 130\ K$$

*Fig. 11-56: Final overtemperature of the motor*

**Final Overtemperature of the Motor Winding**

$$\vartheta_w = \left(\frac{F_{eff}}{F_{n\_motor}}\right)^2 \cdot \vartheta_{wg}$$

$$\vartheta_w = \left(\frac{1313\ N}{1785\ N}\right)^2 \cdot 130K$$

$$\vartheta_w = 70\ K$$

*Fig. 11-57: Final overtemperature of the motor winding*

**Absolute Final Temperature of the Motor Winding**

$$\vartheta_{wabs} = \vartheta_w + \vartheta_{coolant}$$
$$\vartheta_{wabs} = 70\ K + 25\ K$$
$$\vartheta_{wabs} = 95\ °C$$

*Fig. 11-58: Absolute final temperature of the motor winding*

**Reaching the Final Temperature**

The thermal time constant of the selected motor is $T_{th}$ = 7 min. 98% of the final temperature is reached after approximately 4 thermal time constants (i.e. after 28 minutes).

☞ Additional explanations of the thermal behavior of linear motors can be found in chapter 9.6.1 "Thermal Behavior of Linear Motors" on page 116.

## 11.6.2 Machine Tool Feed Axis; Dimensioning via Duty Cycle

### General Information

Detailed information of the motion cycle are sometimes not available or are not exact. In the case of, e.g. small batch production and frequently changing port programs. Sizing of the drives is performed on the basis of the relative duty cycle of different operating phases, and based on empirical values from machine manufacturers and/or machine users.

The following example explains this procedure.

## Specifications

The following data is specified:

Slide mass including motor: $m_S$= 580 kg

Velocity rapid travers: 120 m/min

Velocity handling 15 m/min

Maximum acceleration possible: 15 m/s²

Axis arrangement: horizontally, primary part moved

Motion path 800 mm

Base force: $F_0$ = 600 N (constant)

Maximum machining force: $F_P$ = 1,200 N

Friction coefficient of linear guides: μ = 0.005

Rated connecting voltage: 3 x AC 400V

| Type of machining/movement | Share |
|---:|:---:|
| Acceleration and declaration | 10 % |
| Rapid traverse | 20 % |
| Machining process | 30 % |
| Standstill with machining | 20 % |
| Standstill without machining | 20 % |
| **Total:** | **100 %** |

*Fig. 11-59: Percentage of individual machining processes and movements*

Motor Dimensioning

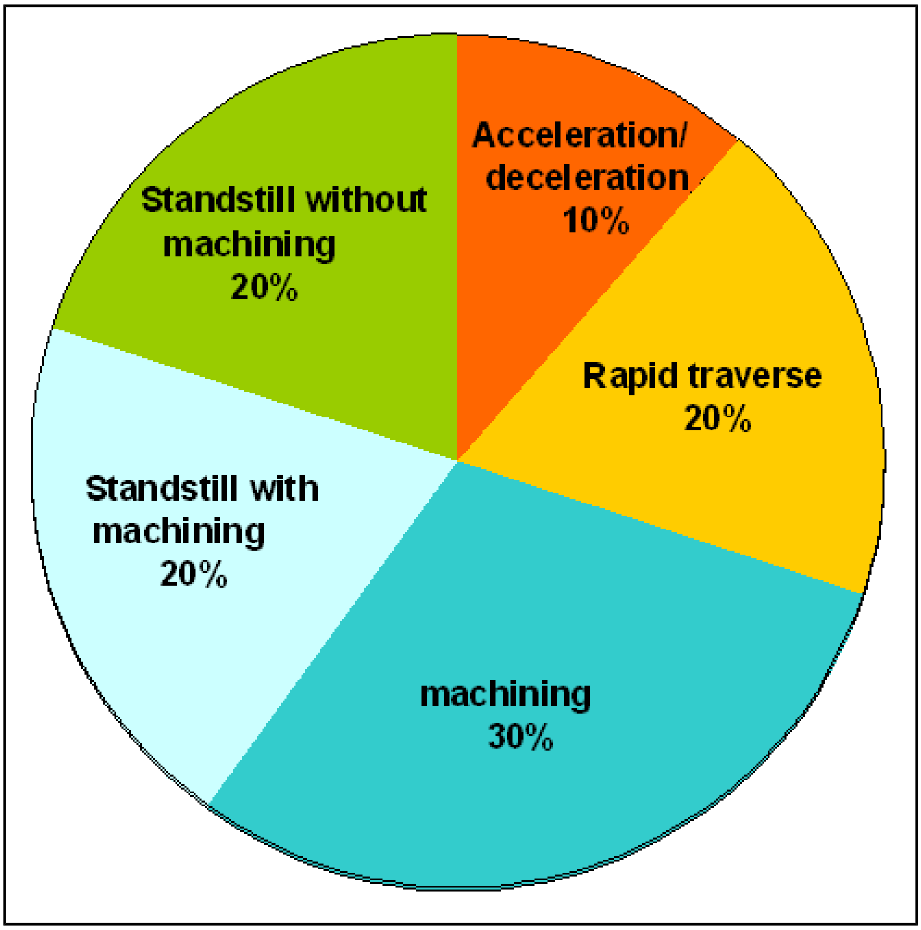



*Fig. 11-60: Graphical presentation of the individual operating phases*

## Calculation

$$F_{acc} = m_{ges} \cdot a$$
$$F_{acc} = 580\,kg \cdot 15\,m/s^2$$
$$F_{acc} = 8700\,N$$

*Fig. 11-61: Acceleration force*

$$F_{max} = F_{acc} + F_0$$
$$F_{max} = 8700\ N + 600\ N$$
$$F_{max} = 9300\,N$$

*Fig. 11-62: Maximum force*

The effective force and the average velocity are determined on the basis of the specifications for the individual operating phases.

| Type of machining/movement | $ED_i$ | Force $F_i$ | | Average velocity $v_{avgi}$ |
|---|---|---|---|---|
| Acceleration and declaration | 10 % | 8700 N | $F_i = F_{acc} \pm F_0$ | 60 m/min |
| Rapid traverse | 20 % | 600 N | $F_i = F_0$ | 120 m/min |

| Type of machining/movement | $ED_i$ | Force $F_i$ | | Average velocity $v_{avgi}$ |
|---|---|---|---|---|
| Machining process | 30 % | 1800 N | $F_i = F_P + F_0$ | 15 m/min |
| Standstill with machining | 20 % | 1200 N | $F_i = F_P$ | 0 m/min |
| Standstill without machining | 20 % | 0 N | | 0 m/min |

*Fig. 11-63: Percentage of individual machining processes and movements*

$$F_{eff} = \sqrt{\sum (F_i^2 \cdot \frac{ED_i}{100})} \qquad v_{avg} = \sum (v_{avgi} \cdot \frac{ED_i}{100})$$

$$F_{eff} = 2983\ N \qquad v_{avg} = 34.5\ m/min$$

*Fig. 11-64: Effective force and average velocity*

## Drive selection

The determined data can be used for selecting a motor-controller combination. The primary part with thermal encapsulation is selected for machine tool applications.

| | |
|---|---|
| Primary part | **MLP140C-0170-FS-N0CN-NNNN**<br>$F_{max\_motor}$: 10,000 N<br>$F_{n\_motor}$: 3,150 N<br>$v_{Fmax\ 750V}$:170 m/min<br>$v_{NENN\ 750V}$: 250 m/min |
| Secondary part segments | **MLS140A-3A-xxxx-NNNN**<br>Total traverse path + primary part length ≈ 1,500 mm |
| Drive device: | **HMS01.1N-W0150** |
| Power supply module: | **HMV** ( $U_{DC}$=750V, regenerative) |
| Linear scale | **Heidenhain LC481**<br>encapsulated, absolute, ENDAT interface |

## Determining the cooling capacity

$$P_{co} = P_{ce} = \left(\frac{F_{eff}}{F_{n\_motor}}\right)^2 \cdot P_{vN\_motor}$$

$$P_{co} = \left(\frac{2983\ N}{3150\ N}\right)^2 \cdot 3400\ W$$

$$P_{co} = 3050\ W$$

*Fig. 11-65: Rated electrical power loss*

The maximum temperature rise at the contact surface of the primary part should not exceed 3 K. The necessary coolant flow in L/min is determined according to:

$$Q = \frac{P_{co} \cdot 25200}{c \cdot \rho \cdot \Delta T_m}$$

$$Q = \frac{3050\ W \cdot 25200}{4183 \frac{J}{kg \cdot K} \cdot 988{,}3 \frac{kg}{m^3} \cdot 3\ K}$$

$$Q = 6.2 \quad \frac{l}{min}$$

*Fig.11-66: Required coolant flow*

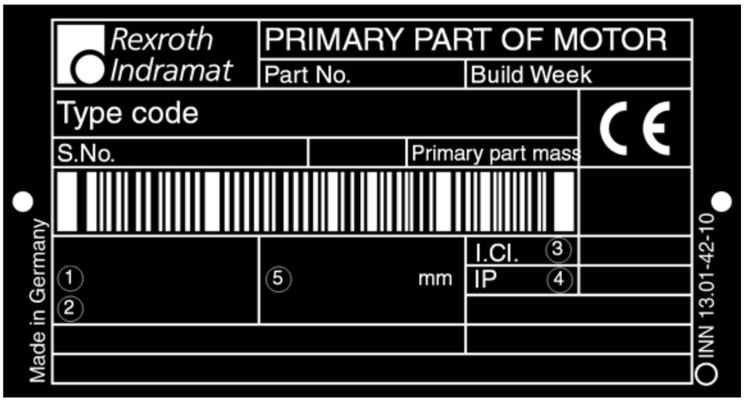
☞ The way of determining the drive power and other more detailed data are not discussed within the scope of this example.

# 12 Handling, Transport and Storage

## 12.1 Identification of the Motor Components

### 12.1.1 Primary Part

On the front of the primary part, on which the connection for the power cable and coolant is arranged, a type plate is fixed. The type plate makes a definite identification of the primary part possible. An additional type plate is attached to the primary part. This type plate can be attached to the machine or can be used otherwise. The type plate of the primary part contains the following data:



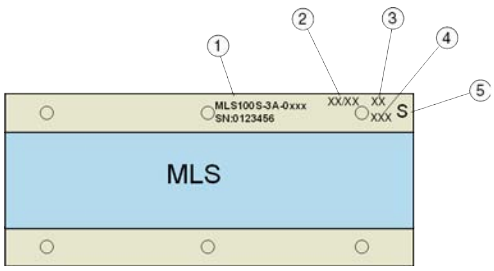

① Rated force (N)
② Rated voltage (A)
③ Insulation class
④ Degree of protection
⑤ Pole pitch (mm)

*Fig. 12-1: Type plate primary part*

### 12.1.2 Secondary Part

On the secondary part can no type plate brought on, because for lack of space. Two identical type plates are attached to the secondary part at delivery. To ensure a safe and permanent identification of the type, the type designation and the serial number are fixed directly on the secondary part.

The type designation and the serial number is located between the first both fixing holes, starting from the front, which is signed with the south pole sign.



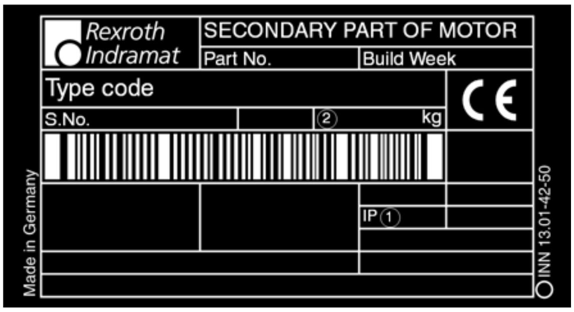

① Type and serial number
② Manufacturing date (month/year)
③ Supplier
④ Number of measurement report
⑤ Pole designation "S" (for south pole)

*Fig. 12-2: Position of the type designation and serial number of the secondary part*

> Each secondary part has a magnetic north pole, unless the length of a front and on the opposite side, a magnetic south pole on the front. The secondary parts are signed with ”S” (south pole) on one front

**Type Plate**

The type plate of the secondary part contains the following data:




① Degree of protection

② Secundary part mass

*Fig. 12-3: Type plate secondary part*

# 12.2 Delivery Status and Packaging

## 12.2.1 Primary Parts

The primary parts are separately packed in a wooden box. To identify the primary part, a type designation exist on the packaging.

## 12.2.2 Secondary Parts

The secondary parts are separately packed in a cardboard box. To identify the secondary part, a type designation exist on the packaging.

**Warnings on the packaging of the secondary parts**

On the packaging of the seconardy parts, a self-adhesive warning label with the following warnings:

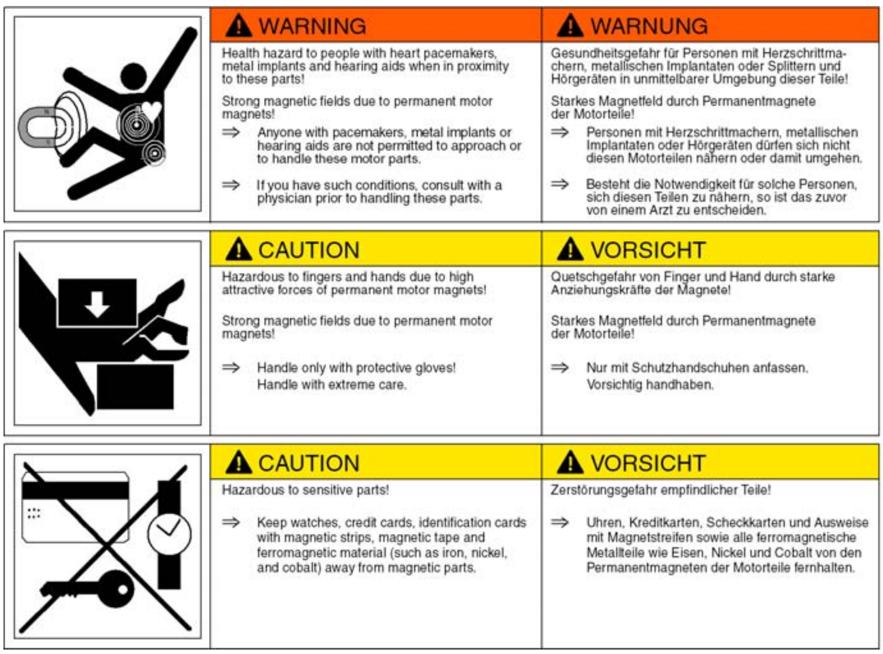



*Fig. 12-4: Warning label on the packaging of MLS secondary parts*

☞ The self-sticking warning label (sizes approx. 110 mm x 150 mm) can be ordered from Rexroth (MNR R911278745).

# 12.3 Transport and Storage

## 12.3.1 Transport

Do the transport and storage of primary and secondary parts in the original packaging, in which the parts were delivered from Bosch Rexroth. Remove the parts from the packaging only then, when the mounting of the parts on the installation place is already done.

The permittable **transport temperature is -20 ... +80 °C**. Strong or periodic temperature variations during the transport are not permitted.

☞ Keep the packaging for later use (retrofitting of the machine, redelivery, etc.).

**Transport Primary Part**

Depending from size and weight of the primary part, it is not possible to transport it by hand. In such cases, a suitable lifting device should be available.

To move the primary part in horizontal position, transport it with ring screws, for example. Heed the thread dimensions within the dimension sheet of the primary part.

CAUTION

**Risk of injury and / or damage when using primary parts!**

⇒ Use both outer threaded holes on every front to screw in the ring screws.

⇒ Screw in the ring screws by hand so far, until the ground of the fastening threas is reached or the contact surface of the ring screws lies on the primary part.

⇒ Use 4 lifting belts for transport to reach a consistant load on the threaded holes and to avoid tilting of the primary part during transport.

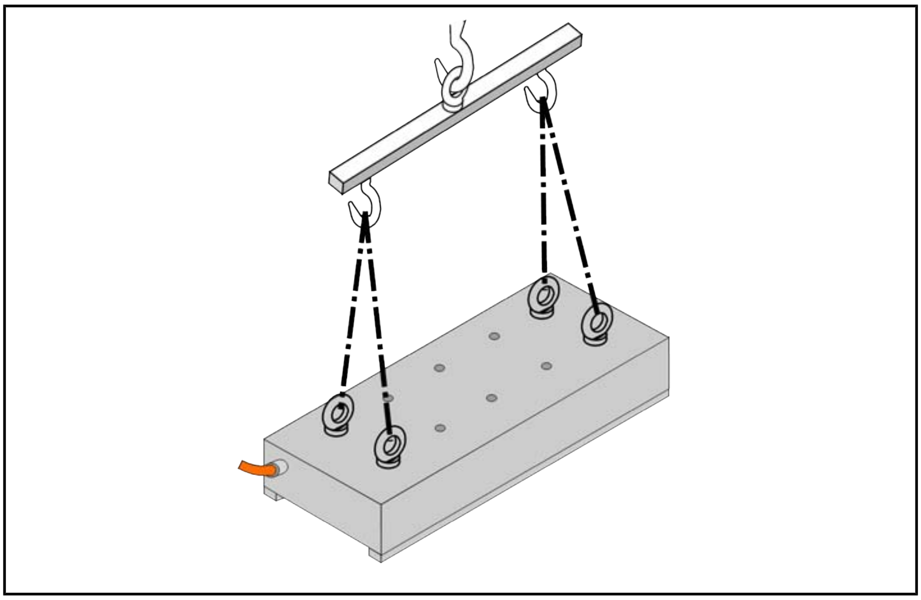


*Fig. 12-5: Transport of a primary part (example)*

**Transport the Secondary Part**

CAUTION

**Risk of injuries and / or damage when handling secondary parts of synchronous linear motors!**

⇒ Heed the safety notes and warnings (refer to fig. 12-4 "Warning label on the packaging of MLS secondary parts" on page 212) when using secondary parts and make sure that they are kept.

⇒ Remove the transport or assembly protection which is stuck on the cover plate only when or after mouning into the machine.

Depending from size and weight of the secondary part, it is not possible to transport it by hand. Due to the strong magnetic field around the secondary part, use anti-magnetic lifting devices.

We recommend to use lifting belts to transport the secondary part.

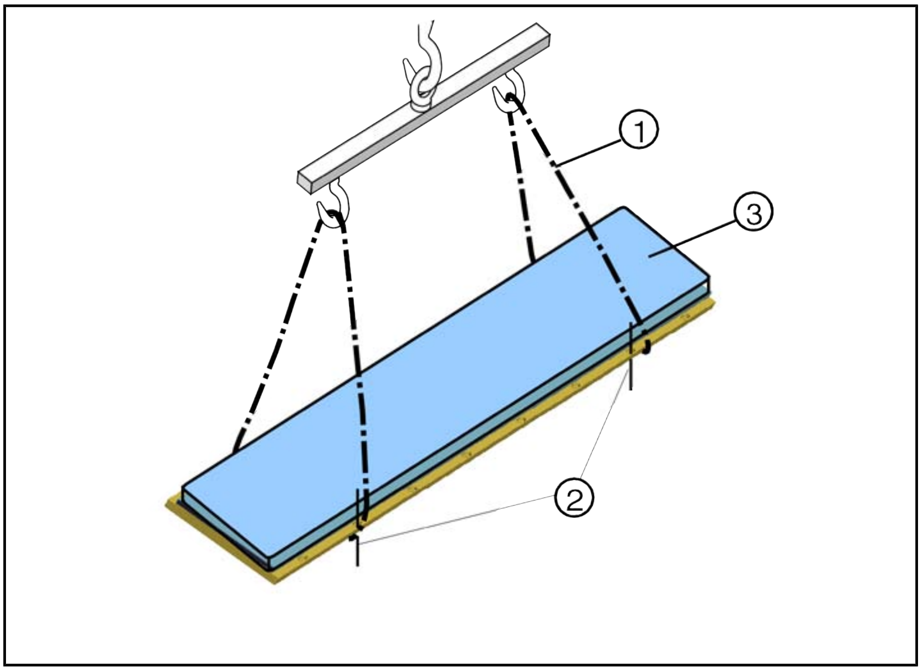
**Safety on the Lifting Belts during Transport**

To avoid that the lifting belts slip together during transport, lock them. Therefore, two fastening screws for the secondary part can be connected into the appropriate hole on the secondary part (see fig. 12-6 "Transport of a secondary part (example)" on page 214). Heed a sufficient excess length of the lock on the lower side of the secondary part.

CAUTION

**Risk of injury and / or damage when using secondary parts!**

⇒ Use an antimagnetic lock during transport of the secondary parts with lifting belts. This lock avoids a possible slip of the lifting belts during transport.




① Lifting belts
② Lock against slipping together of the lifting belts
③ Stuck on transport and assembly protection

*Fig. 12-6: Transport of a secondary part (example)*

**Further Features about Transport of Secondary Parts**

The secondary parts of synchronous linear motors are equipped with permanent magnets, which are not magnetic shielded. The safety notes have to be absolutely adhered.

**Air freight**

CAUTION

**Possible influence of plane electronic on board through magnet fields!**

⇒ Heed the packaging and transport instructions (IATA 902)

### 12.3.2 Bearing

**Storage of Primary and Secondary Parts**

Preferably use the original package to store the parts. If this is not possible under certain circumstances, store the primary and secondary parts of synchronous linear motors on a plain base. This must be ensured even at short time storage.

The permittable **transport temperature is -20 ... +60 °C**. Strong or periodic temperature variations during the storage are not permitted.

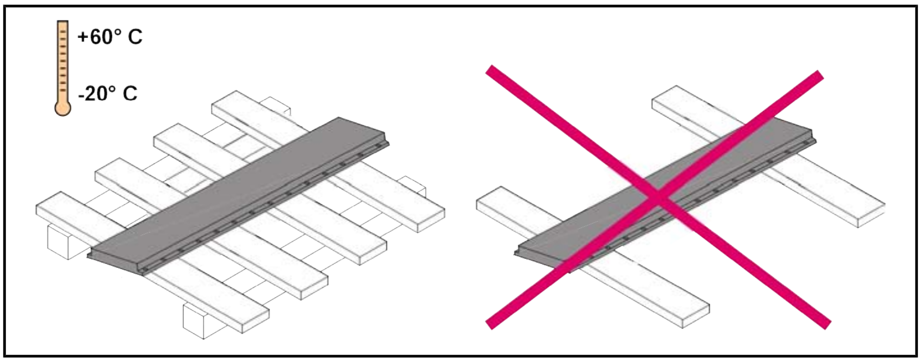



*Fig. 12-7: Storage of linear motor components*

CAUTION

**Inappropriate handling during storage or transport can damage or destroy the motor components!**

⇒ Use the original packaging for permanent storage.

⇒ Short-term storage during installation acc. to fig. 12-7 "Storage of linear motor components" on page 215.

⇒ Do not throw parts.

⇒ Adhere permissible transport and storage temperatures.

⇒ Remove the transportation and installation protection only during or after the installation into the machine.

## 12.4 Checking the Motor Components

### 12.4.1 Factory Checks of the Motor Components

**Electrical inspections**

The Bosch Rexroth linear motors undergo the following electrical checks at the factory:

- High-voltage test acc. to EN 60034-1/2.95 (VDE 0530 Part 1)
- Insulation resistance test acc. to EN 60204-1
- Verification of the specified electrical characteristics

**Mechanical inspections**

The Bosch Rexroth linear motors undergo the following mechanical tests:

- Form and location tolerances acc. to ISO 1101
- Construction and fits acc. to DIN 7157
- Surface structure acc. to DIN ISO1302
- Thread test acc. to DIN 13, Part 20
- Leak test of the cooling circuit

☞ Each motor is accompanied by a corresponding test certificate.

**EMV radia interference suppression**

The linear motor components of Bosch Rexroth have been subjected to an EMV type test and have been certified as complying

**EN 55011 Limit Class B, VDE 0875 Part 11**

## 12.4.2 Incoming Inspection by the Customer

You must contact Bosch Rexroth, if you wish to perform a high-voltage incoming test at customer side.

⚠ CAUTION

**Destruction of motor components due to improperly or repeatedly executed high-voltage inspection!**

⇒ Contact Bosch Rexroth before carrying out tests!

# 13 Assembly

## 13.1 Basic Precondition

Basic precondition for mounting the IndraDyn L components is the keeping of the following basic preconditions:

- Observation of the necessary installation sizes (see fig. 5-1 "Mounting Sizes and Tolerances" on page 49)
- Machine construction fulfills the requests for mounting (stiffness, attractive force, feed force and acceleration force, etc.)
- Machine construction is prepared for mounting of all components
- Clean screw-on surfaces between machine and motor components
- Mounting is done by trained personal
- Compliance of danger and safety notes is guaranteed.

## 13.2 General Procedure at Mounting of the Motor Components

### 13.2.1 General Information

The installation of the motor into the machine construction depends on the arrangement of the secondary part and can be done in different ways.

- Installation at **spanned** secondary parts over the entire traverse path
- Installation at **whole** secondary part over the entire traverse path

☞ The described procedures are only suggestions and can be done user-specific in other forms.

### 13.2.2 Installation at Spanned Secondary Parts over the entire Traverse Path

Installation for a spanned secondary part can be done, as shown in fig. 5-1 "Mounting Sizes and Tolerances" on page 49. Thereby, only a part of the secondary part is installed, so that the primary part can be laid on the machine bed.

WARNING

**Do not lay the primary part directly on the secondary part!**

⇒ Lift-off of the primary part from the secondary part is difficult because of high attractive forces (apparatus necessary).

The assembly of the primary part into the installed slide can be done now. Afterwards, the slide with installed primary part can be pushed over the installed secondary parts. Then, all the remaining secondary parts can be installed.

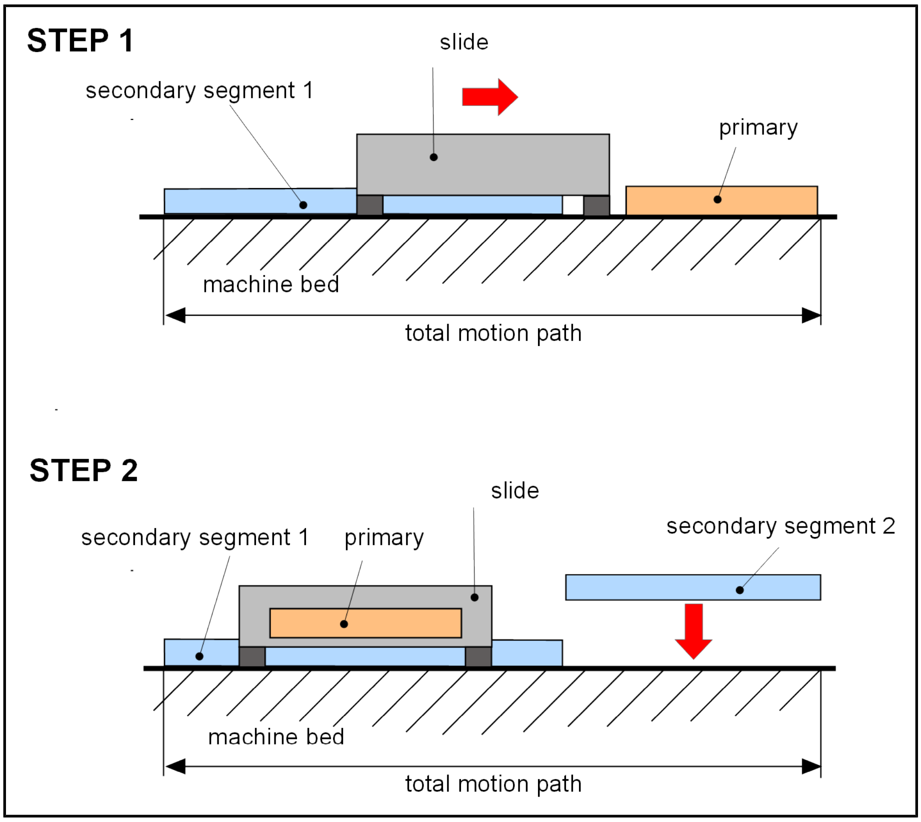



*Fig. 13-1: Assembly of the components of linear motors at spanned secondary part*


**Uncontrolled movement of the slide!**

⇒ Safety against uncontrolled movements by partial covering of primary and secondary parts (force in traverse direction).

## 13.2.3 Installation at Whole Secondary Part over the Entire Traverse Path

At whole secondary part over the entire traverse path can the primary part be installed into the prepared slide. After mounting the secondary part, the slide with prepared primary part can be lowered on the machine bed via a suited apparatus

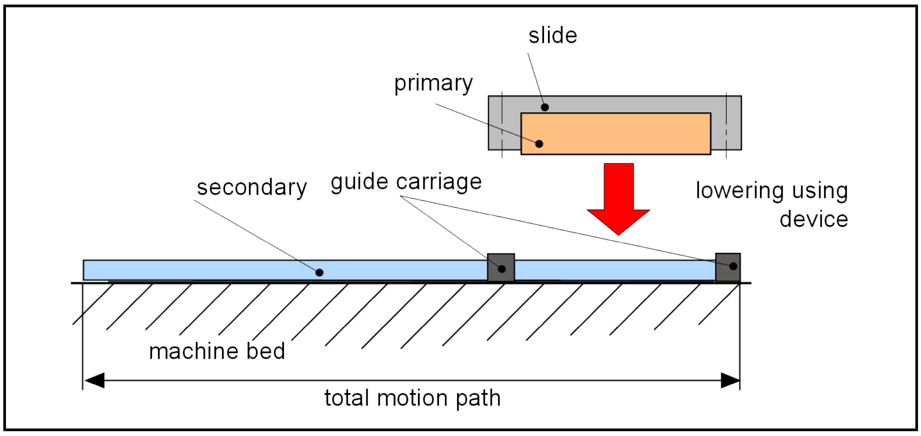



*Fig. 13-2: Installation of the linear motor components at whole secondary part over the entire traverse path*

☞ The apparatus for lowering the primary part and the slide is not in the scope of delivery of Bosch Rexroth.

CAUTION

**When lowering the primary part on the secondary part, result by reducing the air gap increasing attractive forces!**

⇒ Heed the specifications in chapter 9.5 "Feed and Attractive Forces " on page 111.

⇒ Do not lower the primary part on the secondary part with a crane (elasticity / attractive force).

Another possibility is, to lay the primary part on the installed secondary part – with a suited apparatus – and to screw it with fastening screws on the slide. Thereby, a non-ferromagnetic distance plate (made of plastic or wood) has to be laid among the primary and secondary part so that the primary part does not bear on the secondary part directly. The thickness of the distance plate should be measured according to < nominal air gap. After the fastening of the primary part on the slide a moving of the slide should be possible.

The thickness of the distance plate must be measured in such a way that the primary part with the fastening screws can preferably not or only exiguously be lifted.

**Example** Measurable air gap: 1.0 mm

Thickness of the distance plate: 0.95...0.99 mm

The tightening of the fastening screws for the primary part has to be made as described in chapter chapter 13.4 "Installation of the Primary Part" on page 223.

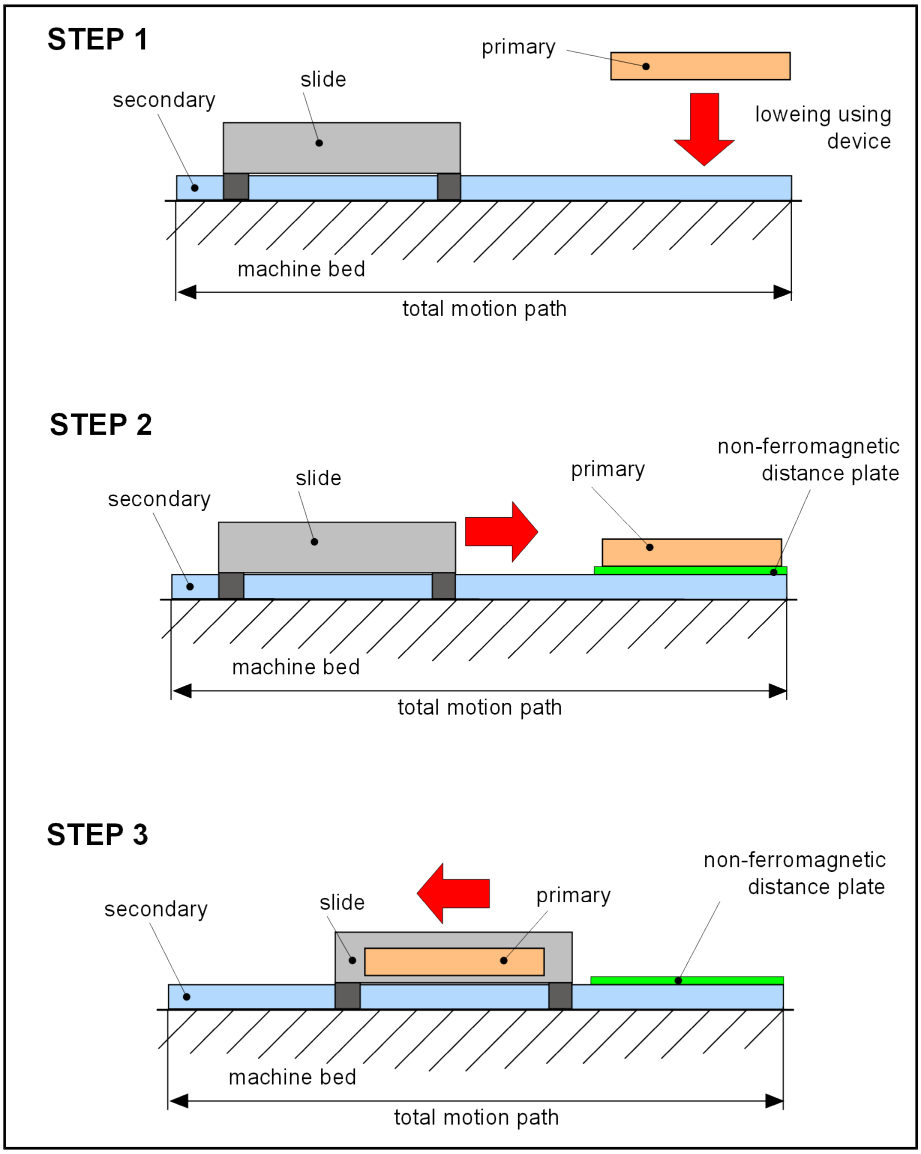



*Fig. 13-3: Installation of the linear motor components at whole secondary part over the entire traverse path*

## 13.3 Installation of Secondary Part Segments

WARNING

**Personal injury and / or damage of motor components!**

⇒ Remove the transport and installation protection of the secondary part only after mounting of the secondary parts.

☞ To fasten the secondary parts, it is only allowed to use new, unused screws.

Tighten all screws with the necessary tightening torque (see fig. 13-4 "Fastening screws with tightening torque for the secondary parts MLS" on page 221). Additionally secure the screw connection with Loctite 243. Therefore note the correct screw locking in chapter 13.7 "Screw Locking " on page 226 at the end of this chapter.

The screw-on surfaces must be cleaned and be free of grease before the secondary parts can be screwed on the machine construction. Certain influences occured during the operation of the motor, e.g. contact of the secondary part with coolants, grinding-emulsion, etc. can reduce the sliding friction between the screw-on parts during the lifetime of the machine. For such cases, we recommend to use fastening screws of a higher property class, e.g. 10.9 to realize a higher tightening torque.

The tightening torque of the specific fastening screws are given as follows:

| Frame size Secondary part | Bolt size- ISO-grade | Property class | Tightening torque (+/-10 %) |
|---|---|---|---|
| 040...200 | M6 (DIN 7984, plain bolt head) | 8.8 | 10 Nm |
| | | 10.9 | 15 Nm |
| 300 | M8 (DIN EN ISO 4762) | 10.9 | 37 Nm |

*Fig. 13-4: Fastening screws with tightening torque for the secondary parts MLS*

The calculation of the screw connection to fasten the secondary parts is based on the presumption that both, the screw-on surfaces of the secondary part and on the machine are cleaned and the secondary part is directly screwed with the machine (see fig. 9-41 "Cooling concept for thermal encapsulation" on page 119).

☞

- In certain cases, the secondary part cannot be screwed directly with the machine, because additional materials like distance plates, heat-conductive paste etc. are between the secondary part and the machine. Therefore, a sufficient property of the screw-connection must be ensured by the machine manufacturer.
- The effect of liquid screw locking is damaged due to loosening or re-tightening of the screws (e.g. due to torque check) and must be carried out again. Notes regarding correct execution of the screw locking can be found in chapter 13.7 "Screw Locking " on page 226.

Spanned secondary part

WARNING

**Malefunction and / or uncontrolled movement of the motor result in danger of damage or risk of injury!**

⇒ Correct arrangement of the secondary part segments.

Using several arranged secondary part segments over the entire traverse path, the pole series and the aligned adjustment must be kept according to the following figure.

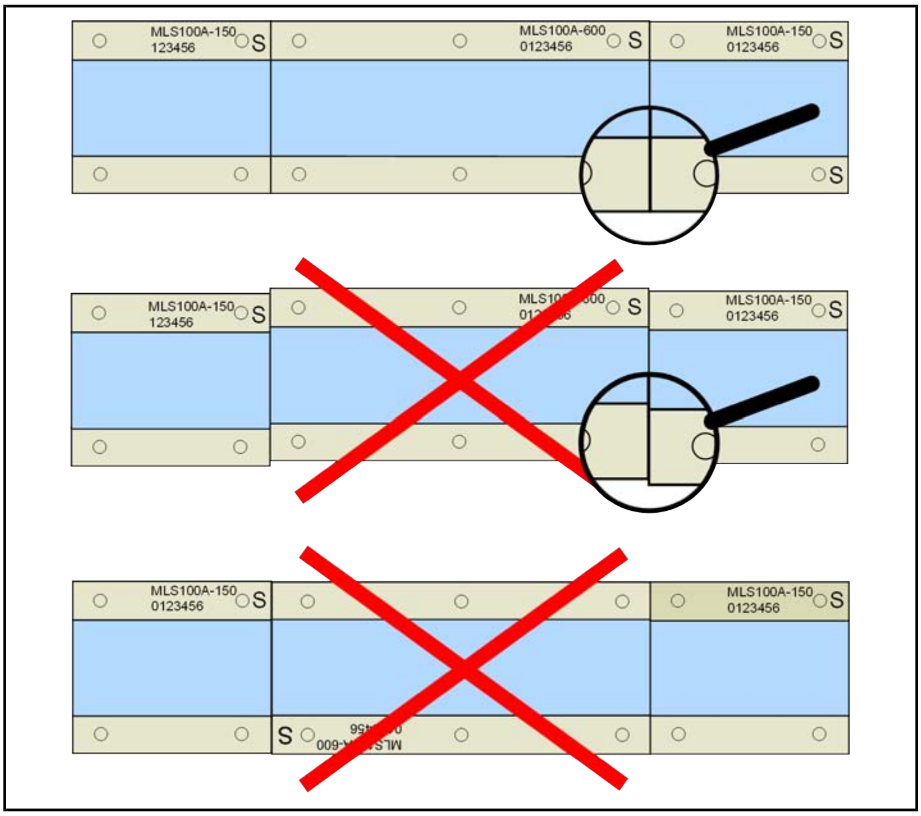



*Fig. 13-5: Arrangement of several secondary parts*

WARNING

**Risk of injury or damage by attractive force or repulsive force when arranging the secondary part segments!**

⇒ Safety against uncontrolled movement

⇒ Remove the transportation and installation protection only during or after the installation into the machine.

Attractive or repulsive forces can be approx. 300 N differing from the size, when arranging the secondary part segments.

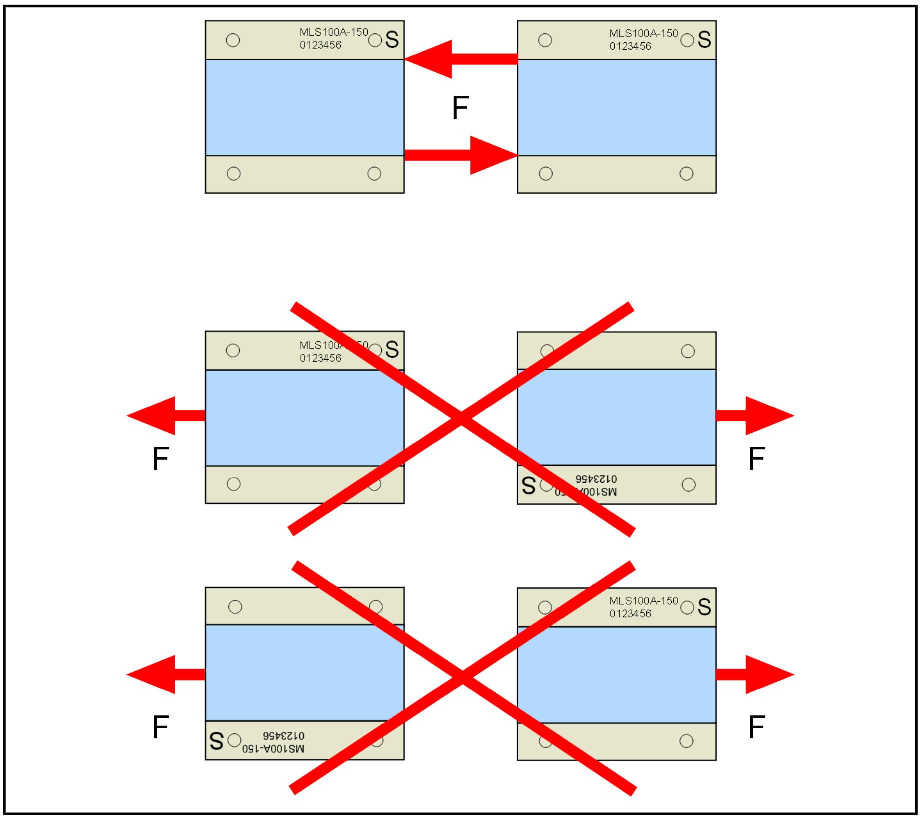



*Fig. 13-6: Attractive or repulsive force when arranging the secondary part segments*

## 13.4 Installation of the Primary Part

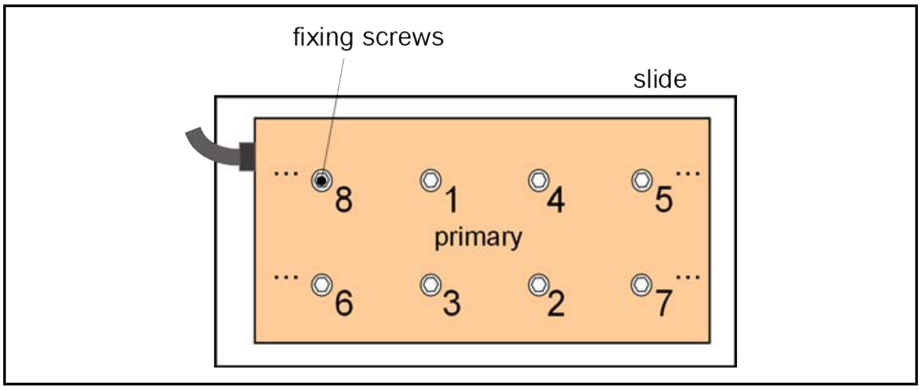



*Fig. 13-7: Order of tightening the fastening screws of the primary part*

The screw-on surfaces must be cleaned and be free of grease before the primary part can be screwed on the machine construction. Certain influences occured during the operation of the motor, e.g. contact of the primary part with coolants, grinding-emulsion, etc. can reduce the sliding friction between the screw-on parts during the lifetime of the machine. For such cases, we recommend to use fastening screws of a higher property class, e.g. 10.9 to realize a higher tightening torque.

Mounting instructions:

1. Prepare threaded holes and screws (procedure see chapter 13.7 "Screw Locking " on page 226).

2. Fasten the primary part with screws 1, 2, 3...x until the primary part lies on the slide.
3. Fasten screws 1, 2, 3 ...x with nominal tightening torque:

| Frame size Primary part | Bolt size- ISO-grade | Property class | Tightening torque (+/-10 %) |
|---|---|---|---|
| 040...300 | M6 (DIN 7984, plain bolt head) | 8.8 | 10 Nm |
| | | 10.9 | 15 Nm |

*Fig. 13-8: Nominal tightening torque for the fastening screws of the primary parts*

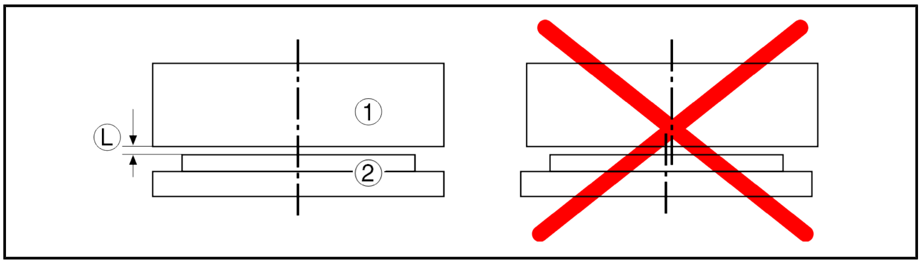
☞ The effect of liquid screw locking is damaged due to loosening or re-tightening of the screws (e.g. due to torque check) and must be carried out again. Notes regarding correct execution of the screw locking can be found in chapter 13.7 "Screw Locking " on page 226.

## 13.5 Air-gap, Parallelism and Symmetry among the Motor Components

**Parallelism and Symmetry**

When mounting primary and secondary parts, their position is specified by the holes or threads within the machine slide and within the machine bed (seefig. 5-2 "Parallelism and symmetry between the fastening holes for the primary part and the fastening threads for the secondary part" on page 50).

As a small tolerance exists within the holes of the screw connections, the parts must be averaged and arranged according to fig. 13-5 "Arrangement of several secondary parts" on page 222 before the screws are finally tightened.




① Primary part
② Secondary part
(L) Air gap

*Fig. 13-9: Aligning the motor components*

**Air gap**

We recommend after mounting the motor components, to check the minimum necessary air gap between primary and secondary part.

Therefore, a test strip made of antimagnetic material (aluminum, plastics etc.) of a thickness of

- **0.5...0.55 mm** (for frame size 040...200)
- **0.7...0.75 mm** (for frame size 300)

must be inserted into the air gap between primary and secondary part. The test strip must be freemoving on each point within the whole traverse path of the air gap.

With this measure, you will prevent that the minimum necessary air gap exists between the motor parts.

Furthermore, with this test you will detect a faulty assembly (e.g. due to dirt unter the mounting surface, faulty installation dimension, unsufficient machine rigidity etc.) in time.

CAUTION

**Motor damage due to unsufficient air gap between primary and secondary part!**

Immediately check the necessary minimum air gap between primary and secondary part after the assembly of both motor components by means of the aforementioned measures.

## 13.6 Connection Liquid Cooling

Connection of the liquid cooling is made by standard threads directly on the primary part.

☞ Fittings and coolant pipes are not in the scope of delivery of the linear motor.

**Tightening torque**

The indicated tightening torque (see fig. 13-10 "Connection liquid cooling" on page 225) of the thread on the motor should not be exceeded.

Heed that depending on the form of the selected connection thread, the value possibly cannot be used, but rather be reduced to do not damage the connection thread.

☞ Observe the information of the manufacturer of the selected connection thread, especially the details about the permitted tightening torque.

The motor-sided coolant connections are designed for coolant connection threads with axial sealing.

Bosch Rexroth recommends to use connection threads, which contain an O-Ring for axial sealing of the screw connection.

Not suited is a sealing using hemp bred, teflon tape or even with conical threads as this kind of sealing can stress and/or even damage the connection thread on the motor

☞ The impermeability of the coolant connection is in the responsibility of the machine manufacturer and has to be tested and acceptet by him after installing the motor.

Furthermore, a regular test of correct state of the coolant connection should be stored in the maintenance plan of the machine.

The following connection data have to be kept. Exceeding the tightening torque or depth of engagement can lead to irreversible motor damage.

| Primary part with... | Thread on the motor side | | |
|---|---|---|---|
| | Thread | Tightening torque | Depth of thread |
| Standard encapsulation | G1/4 | max. 30 Nm | max. 12 mm |
| Thermal encapsulation | | | |

*Fig. 13-10: Connection liquid cooling*

# 13.7 Screw Locking

## 13.7.1 General Information

**General Information**

LOCTITE is a plastic adhesive, which is applied to the installation parts in liquid form. The adhesive remains liquid as long as it is in contact with oxygen. Only after the parts have been mounted, it converts from its liquid state into hard plastic. This chemical conversion takes place under exclusion of air and the produced metallic contact. The result is a form-fitting connection that is impact- and vibration-resistant. Sie ist stoß- und vibrationsfest. The hardening accelerator Activator 7649 reduces the hardening time of the adhesive.

**Gluing**

**Proceed as follows:**

1. Clean metal shavings and coarse dirt from threaded hole and screw or grub screw.
2. Use LOCTITE rapid cleanser 7061 to clean oil, grease and dirt particles from threaded hole and screw/grub screw. The threads have to be absolutely restless.
3. Spray LOCTITE activator into the threaded hole and let it dry.
4. Use LOCTITE adhesive to moisten the same threaded hole in its entire thread length thinly and evenly.
5. Screw in the matching screw/grub screw.
6. Allow join to harden. Hardening times see fig. 13-11 "Hardening times LOCTITE adhesive" on page 226.

## 13.7.2 Securing Screwed Connections using LOCTITE in Tapped Blind Holes

The adhesive must always be dosed into the tapped hole, never on the screw. This prevents that the compressed air extrudes the adhesive when the screw or grub screw is screwed in.

| | Hardened | Hard to the touch without activator | Hard to the touch with activator 7649 |
|---|---|---|---|
| LOCTITE 243 | ≈ 12 h | 15...30 min | 10..0.20 min |
| LOCTITE 620 | ≈ 24 h | 1...2 h | 15...30 min |
| NOTE: All values refer to the hardening time at room temperature. The times are shorter when heat is added. | | | |

*Fig. 13-11: Hardening times LOCTITE adhesive*

☞ LOCTITE 620 is heat-resistant up to 200 °C,
LOCTITE 243 up to 150 °C.

**Detach the connection**

To detach the connection, use a wrench for unscrewing the screw or grub screw in the traditional way. The breakaway torque of LOCTITE 620 is 200.45 Nm, the one of LOCTITE 243 is 140.34 Nm (acc. to DIN 54 454). Blowing hot air on the screw connection reduces the breakaway torque.

Is the screw/grub screw removed, the residuals of the adhesive must be removed from the threaded hole (e.g. re-cutting the thread).

NOTE: The German version of the chapter was checked by LOCTITE Germany for correctness and was approved for publication.

# 14 Commissioning, Operation and Maintenance

## 14.1 General Information for Startup of IndraDyn L Motors

The startup of linear motors is different to the rotative servo motors. The differences are described in this chapter.

☞ Use the functional description of the drive controller for more additional information

The following points have to be especially noticed when startup synchronous-linear motors.

**Parameter** Synchronous-linear motors are kit motors whose single components are – completed by an encoder system – directly installed into the machine by the manufacturer. As a result of this, kit motors have no data memory to supply motor parameters or standard controller adjustment. At startup, all parameters have to be manually entered or loaded into the drive. The startup-program DriveTop makes all motor parameters of Bosch Rexroth available.

**Controller Optimization** The procedure used for optimizing the control loops (current, velocity and position controllers) of linear direct drives corresponds to the one used for rotary servo drives. At linear drives are only the adjustment limits higher. At linear direct drives compared with rotative servo drives can be, for example, a 10-fold higher kv-factor adjusted. Precondition therefore is an appropriate machine construction (see chapter 9.3 "Requirements on the Machine Design" on page 102).

**Moving Masses** At controlled rotative servo drives are automatic-control engineering modifications at the rate of motor-moment of inertia to demand-moment of inertia. Such a modification is not available for direct drives with linear motors. The moved foreign mass is independent from the motor self-mass.

**Encoder Polarity** The polarity of the actual-speed (length measuring system) must agree with the force polarity of the motor. This connection has to be established before commutation-adjustment.

**Commutation Adjustment** It is necessary at synchronous linear motors to receive the position of the primary part relating on the secondary part by return after start or after a malfunction. This is called identification of pole position or commutation adjustment. The commutation adjustment-process is the establishment of a position reference to the electrical or magnetic model of the motor. The commutation adjustment can be done after installation of the motor components and length measuring system. The way of doing the commutation adjustment complies with the measuring principle of the length measuring system.

## 14.2 General Precondition

### 14.2.1 General Information

The following preconditions have to be created for a successful start-up.

- Adherence of the safety regulations and notes.
- Check of electrical and mechanical components on a safe function.
- Availability and supply of required implements.
- Adherence of the following described start-up

### 14.2.2 Adherence of all Electrically and Mechanically Components

Do a check of all electrically and mechanically components before start-up. Heed the following points in particular:

☞

- Safety warranty of personnel and machine
- Proper installation of the motor
- Correct power connection of the motor
- Correct connection of the length measuring system
- Function of available limit switch, door switch, a.s.o.
- Proper function of the emergency stop circuit and emergency stop.
- Machine construction (mechanical installation) in proper and complete condition.
- Availability and function of suitable end-of-stroke damper.
- Correct connection and function of the motor cooling.
- Proper connection and function of the drive control unit.

WARNING

**Danger to life, heavy injury or damage by failure or malfunction on mechanical or electrical components!**

⇒ Troubleshooting at mechanical or electrical components before continue with the start-up.

### 14.2.3 Implements

**Start-up software DriveTop** The start-up can be made directly via a NC-terminal or via a special software. The start-up software DriveTop makes a menu-driven, custom-designed and motor specific parameterizing and optimization possible.

**PC** For start-up with DriveTop is a usual Windows-PC needed.

**Start-up via NC** For start-up via NC-control unit, access to all drive parameters and functionalities must be guaranteed.

**Oscilloscope** An oscilloscope is needed for drive optimization. It serves to display the signals, which can be shown via the adjustable analog output of the drive controller. Viewable signals are, e.g. nominal and actual values of the speed, position or voltage, position lag, intermediate circuit a.s.o.

**Multimeter** At troubleshooting and check of the components can be a multimeter with the possibility to voltage metering and resistor measuring helpful.

## 14.3 General Start-Up Procedure

In the following flow-chart is the general start-up procedure at synchronous linear motors MLF shown. In the following chapters are these points explained in detail.

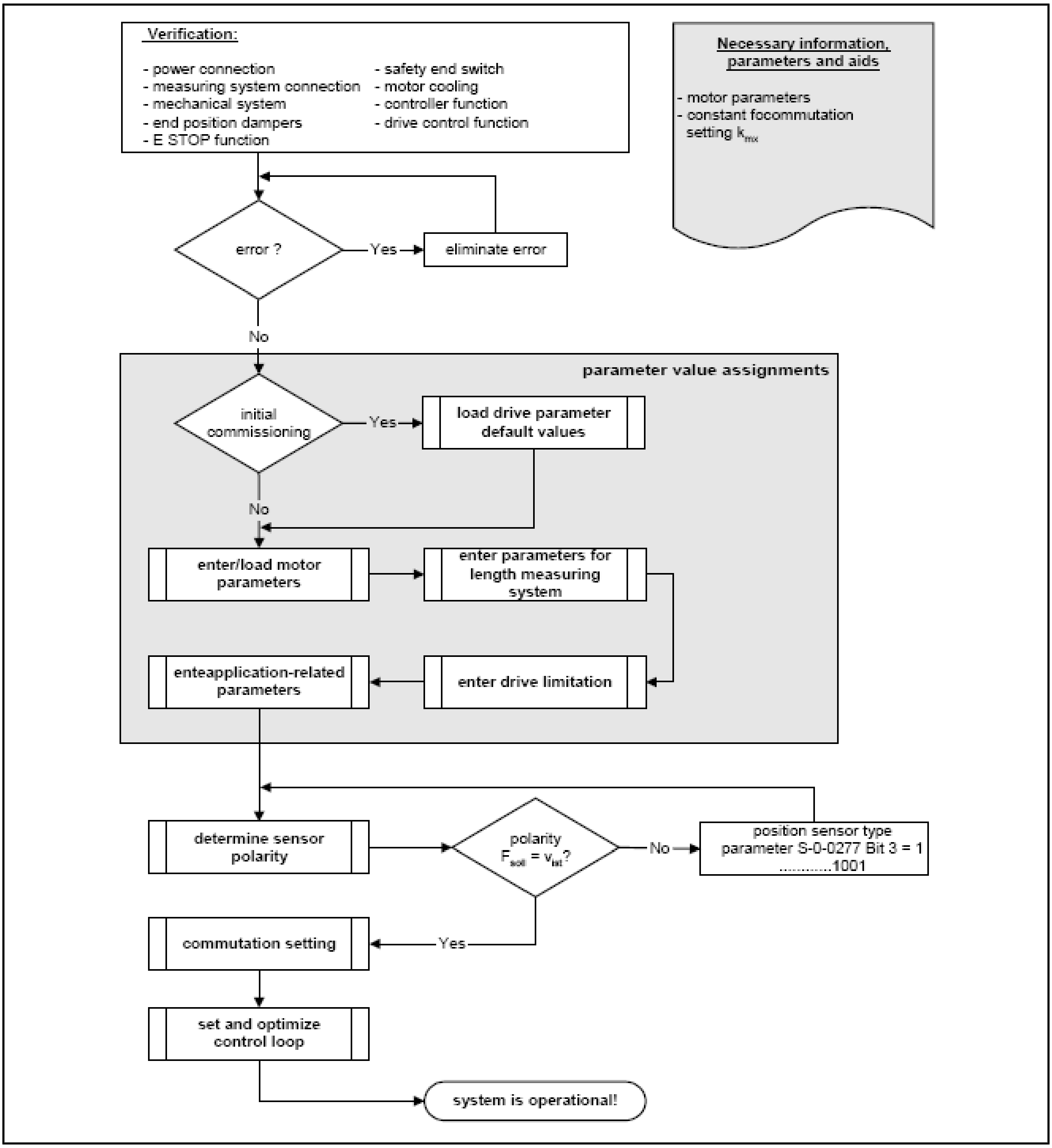



*Fig.14-1: General start-up procedure at synchronous linear motors*

# 14.4 Parameterization

## 14.4.1 General Information

With DriveTop, entering or editing certain parameters and executing commands during the commissioning process is done inside menu-driven dialogs or in list representations. Optionally, it can also be performed via the control terminal.

## 14.4.2 Entering Motor Parameters

☞ The motor parameters are specified by Rexroth and must not be changed by the user. Commissioning is not possible, if these parameters are not available. In this case, please get into contact with your Rexroth Sales and Service Facility.

**WARNING**

**Injuries and mechanical damage, if the motor is switched on immediately after the motor parameters have been entered! Entering the motor parameters does not make the motor operational!**

⇒ Do not switch on the motor immediately after the motor parameters have been entered.

⇒ Enter the parameters for the linear scale.

⇒ Check and adjust the measuring system polarity.

⇒ Perform commutation setting

The motor parameters can be entered in the following way:

- Use DriveTop to load all the motor parameters.
- Enter the individual parameters manually via the controller.
- With series machines, load a complete parameter record via the controller or DriveTop.

## 14.4.3 Motor Parameter at Parallel Arrangement

Are two linear motors operated in a control device, the following parameters have to be adjusted when commisioning:

| Parameter | Designation | Matching coefficient |
|---|---|---|
| P-0-4016 | Direct-axis inductance of motor | x 0.5 |
| P-0-4017 | Quadrature-axis inductance of motor | x 0.5 |
| P-0-4048 | Stator resistance | x 0.5 |
| S-0-0116 | Current loop proportional gain 1 | x 0.5 |
| S-0-0109 | Motor peak current | x 2 |
| S-0-0111 | Motor current at standstill | x 2 |

*Fig. 14-2: Parameter adjustment at parallel arranagement*

☞ If not the maximum possible continuous nominal force or the maximum possible peak load of the motor is necessary, a smaller drive device can be used. In this case, the setting of the mentioned currents must be adjusted to the selected drive device.

## 14.4.4 Operation of IndraDyn L Synchronous Linear Motors without Liquid Cooling

**WARNING**

**Motor damage! Overheated winding!**

⇒ If the current on a water-cooled motor is not accordingly reduced, then the motor heats-up so fast at 2.2x rated current that not in any case the thermal contacts cannot switch-off the motor on time. An overheated winding is the consequence. Due to the overheated winding, the winding insulation is weak or in an extreme case destroyed.

Without liquid coolant only reduced power data are available. These are listed in this documentation.

The stated values in the data sheets regarding rated force and rated current of the motors must be lowered depending on the coupling of the motors to ~40% of the stated value.

If this current reduction is not recorded in the parameter S-0-0111 (standstill motor), the 2.2-times of the water-cooled rated current can be applied to the motor, if necessary (for a stipulated period of time in the parameter P-0-4035). This current is by the factor 2.5 too high for the non-water cooled IndraDyn L motor.

**Example:**

Rated current for the **water cooled motor** = 10A

S-0-0111 = 10 A

Possible current = 2.2 x 10 A = **22 A**

Rated current for the same motor design, but **not water-cooled**:

S-0-0111 = 10 A x 0.4 = 4 A

Possible current = 2.2 x 4 A = **8.8 A**

---

☞ Notice the details in chapter 9.6.4 "Operation of IndraDyn L Synchronous Linear Motors without Liquid Cooling" on page 123 about operation of an IndraDyn L motor without liquid cooling.

---

### 14.4.5 Input of Linear Scale Parameters

**Encoder type**

The type of the linear scale must be defined. Therefore serves the parameter P-0-0074, Encoder type 1.

| Encoder type | P-0-0074 |
|---|---|
| **Incremental measuring system**, e.g. LS486 in conjunction with high-resolution DLF position interface | 2 |
| **Absolute encoder with ENDAT interface**, e.g. LC181 in conjunction with high-resolution DAG position interface | 8 |

*Fig. 14-3: Encoder type definition*

**Signal period**

Linear scale for linear motors generate and interpret **sinusoid signals**. The sine signal period must be entered in the parameter S-0-0116, sensor 1 resolution.

---

☞ The details about the values for the parameter S-0-0116, Encoder 1 resolution is done in fig. 9-81 "Recommended linear scales for linear motors" on page 143. The values for the linear scale that are not shown in this figure must be obtained directly from the manufacturer.

---

### 14.4.6 Input of Drive Limitations and Application-Related Parameters

**Drive Limitations**

The possible selectable drive limitations include:

- Current limitation
- Force limitation
- Velocity limitations
- Travel range limits

**Application-Related Parameters**

The application-related drive parameters include, for example, the parameters of the drive fault reaction.

☞ Detailed information can be found in the description of function of the employed drive controller and/or Firmware.

## 14.5 Determining the Polarity of the Linear Scale

In order to avoid direct feedback in the velocity control loop, the effective direction of the motor force and the count direction of the linear scales must be the same.

WARNING

**Different effective directions of motor force and count direction of linear scale cause uncontrolled movements of the motor upon power-up!**

⇒ Safety against uncontrolled movement

⇒ Adjust effective direction of motor force equal to linear scale count direction.

**Effective Direction of Motor Force**

To set the correct sensor polarity:

**The effective direction of the motor force is always positive in the direction of the cable connection of the primary part.**

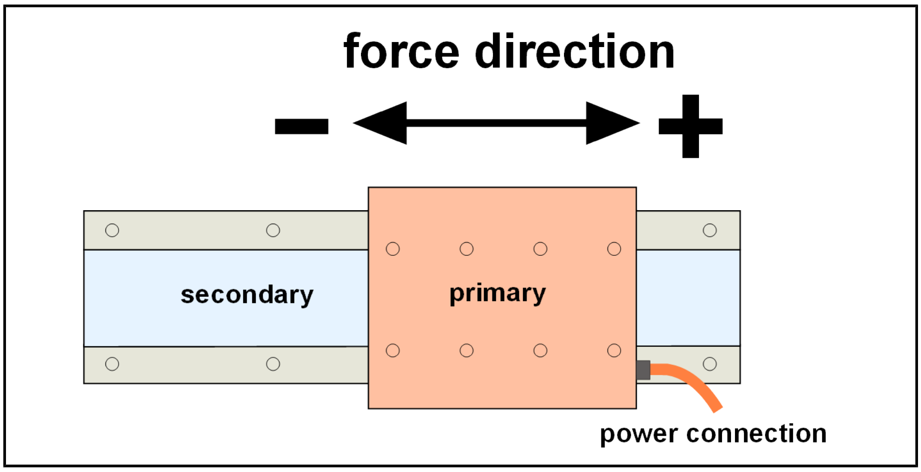



*Fig. 14-4: Effective direction of motor force*

**Effective Direction Motor Force = Linear Scale Count Direction**

When the primary part is moved in the direction of the cable connection, the count direction of the linear scale must consequently be positive:

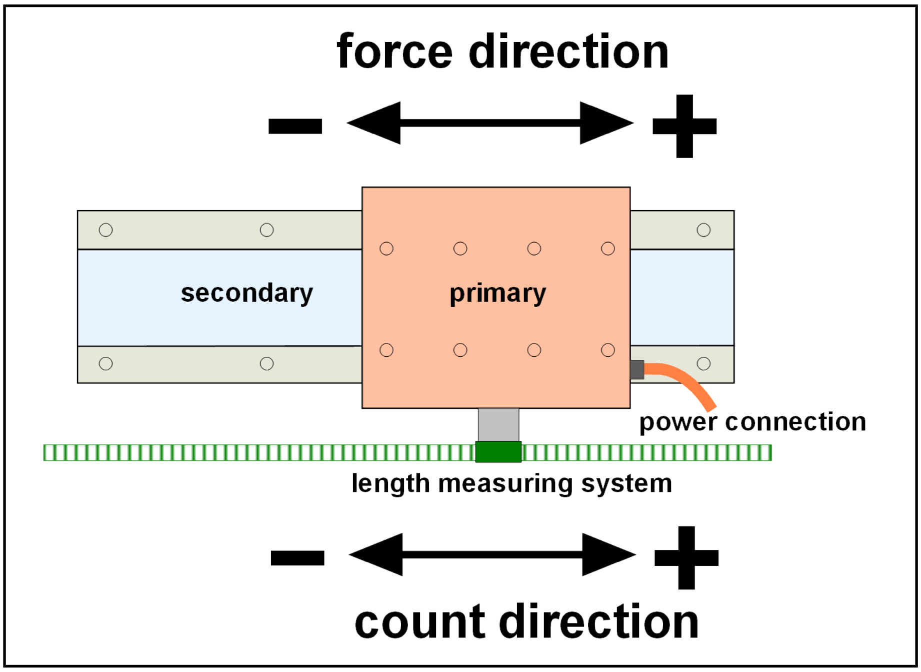



*Fig. 14-5: Effective direction motor force = linear scale count direction*

---

☞ The encoder polarity is selected via the primary part (cable connection). The installation direction or the pole sequence of the secondary part does not have any influence on the selection of the sensor polarity.

---

The encoder polarity is selected via the parameter

**S-0-0277, position encoder type 1 (Bit 3)**

Position, velocity and force data must not be inverted when the linear scale count direction is set:

S-0-0085, Force polarity parameter 0000000000000000

S-0-0085, Velocity polarity parameter 0000000000000000

S-0-0085, Position polarities 0000000000000000

The process-related axis count direction is set as required **after** sensor polarity and commutation have been set.

# 14.6 Commutation Adjustment

## 14.6.1 General Information

Setting the correct commutation angle is a prerequisite for maximum and constant force development of the synchronous linear motor.

This procedure ensures that the angle between the current vector of the primary part and the flux vector of the secondary part is always 90°. The motor supplies the maximum force in this state.

**Adjustment Procedure**

**Three** different commutation adjustment procedures have been implemented in the firmware. The figure below shows the correlation between the employed linear scale and the method that is to be use.

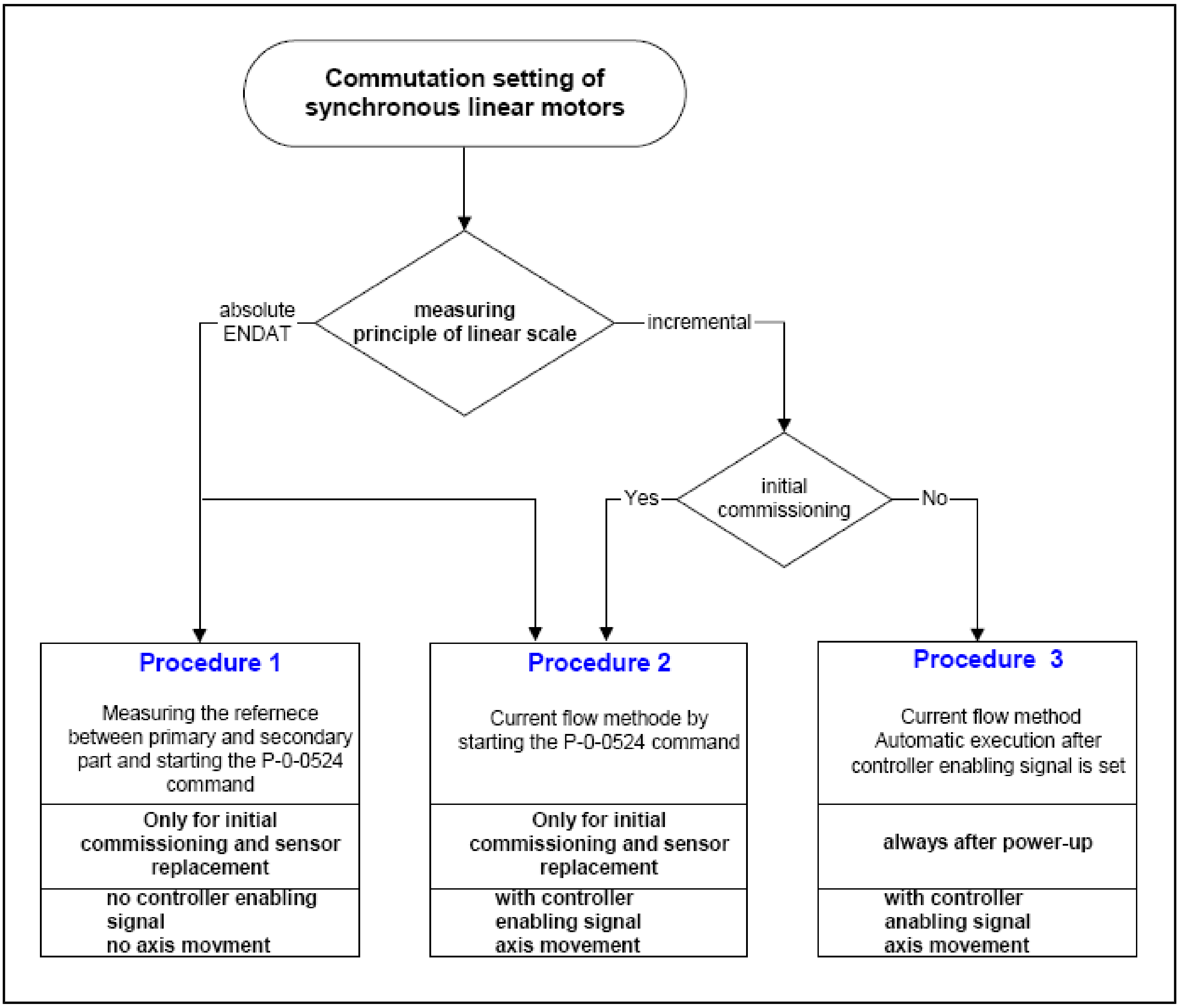



*Fig. 14-6: Commutation adjustment method for synchronous linear motors*

☞ The three methods are described subsequently.

☞ The methods 2 and 3 cannot be used for: - vertical axes without weight compensation -clamped or blocking axes

**DANGER**

**Malfunction due to errors in trigger motors and moving elements! Commutation adjustment must always be performed in the following cases:**

⇒ Initial start-up

⇒ Modification of the mechanical attachment of the linear scale

⇒ Replacement of the linear scale

⇒ Modification of the mechanical attachment of the primary and/or secondary part

**WARNING**

**Malfunction and/or uncontrolled motor movement due to error in commutation adjustment!**

⇒ Effective direction motor force = linear scale count direction

⇒ Adhering to the described setting procedures

⇒ Correct motor and encoder parameterization

⇒ Expedient parameter values must be assigned for current and velocity control loop.

⇒ Correct connection of motor power cable

⇒ Protection against uncontrolled movements

**Motor Connection**

The individual phases of the motor power connection must correctly be assigned. See also Chapter 8 ”Electrical Connection”.

**Parameter Verification**

To ensure a correct commutation adjustment, the following parameters should be checked again and, if necessary, set to the values specified below:

| Identity number | Description | Value |
|---|---|---|
| S-0-0085 | Torque/force polarity parameter | 0000000000000000 |
| S-0-0043 | Velocity polarity parameter | 0000000000000000 |
| S-0-0055 | Position polarities | 0000000000000000 |
| P-0-4014 | Type of construction of motor | 3 (synchronous linear motor) |
| P-0-0018 | Number of pole pairs/pole pair distance | 75 |
| S-0-0116 | S-0-0016, Feedback 1 Resolution | fig. 9-81 "Recommended linear scales for linear motors" on page 143 |

*Fig. 14-7: Parameters that must be checked prior to commutation adjustment*

## 14.6.2 Method 1: Measuring the Reference between Primary and Secondary Part

If this procedure is used for commutation adjustment, the relative position of the primary part with respect to the secondary part must be determined. The benefit of this procedure is that the commuation adjustment requires neither the power to be switched on nor the axes to be moved. Commutation adjustment need only be performed during the first-time commissioning.

☞ This procedure requires an absolute linear scale with ENDAT interface.

**Measuring the relative position between primary and secondary part**

Depending on the accessibility of primary and secondary part in the machine or system, the relative position between primary and secondary part can be measured in different ways.

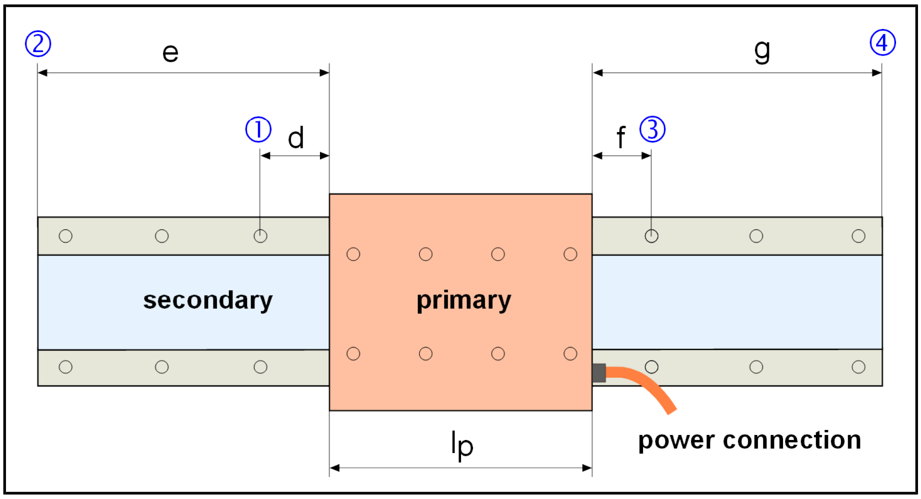



*Fig. 14-8: Measuring the relative position between primary and secondary part*

☞ From now on, the position of the primary part must not be changed until the commutation adjustment procedure is terminated!

**Calculation of P-0-0523, commutation adjustment measured value**

The input value for P-0-0523 that is required for calculating the commutation offset, is determined from the measured relativce position of the primary part with respect to the secondary part (fig. 14-8 "Measuring the relative position between primary and secondary part" on page 236, distance d, e, f or g, depending on accessibility), and a motor-related constant $k_{mx}$ (see fig. 14-9 "Calculation of P-0-0523, commutation adjustment measured value" on page 236 and fig. 14-11 "Motor constants for commutation adjustment kmx " on page 237).

$$\text{Reference point 1:} \quad P-0-0523 = d - k_{mx}$$

$$\text{Reference point 2:} \quad P-0-0523 = e - k_{mx} - 37.5\ \text{mm}$$

$$\text{Reference point 3:} \quad P-0-0523 = -f - l_p - k_{mx}$$

$$\text{Reference point 4:} \quad P-0-0523 = 37.5\ \text{mm} - g - l_p - k_{mx}$$

| | |
|---|---|
| P-0-0523 | Commutation adjustment measured value in mm |
| d | Relative position 1 in mm (Fig. 14-8) |
| e | Relative position 5.08 cm mm (Fig. 14-8) |
| f | Relative position 7.62 cm mm (Fig. 14-8) |
| g | Relative position 10.16 cm mm (Fig. 14-8) |
| $k_{mx}$ | Motor constant for commutation adjustment in mm |
| $l_P$ | Length of primary part in mm |

*Fig. 14-9: Calculation of P-0-0523, commutation adjustment measured value*

☞ Ensure that the sign is correct when you determine P-0-0523, commutation adjustment measured value. If P-0-0523 is determined with a negative sign, this must be entered when the setup procedure is started.

**Motor Constant for Commutation Adjustment kmx**

The motor constants for adjusting the commutation offset $k_{mx}$ depend on the orientation of primary and secondary part:

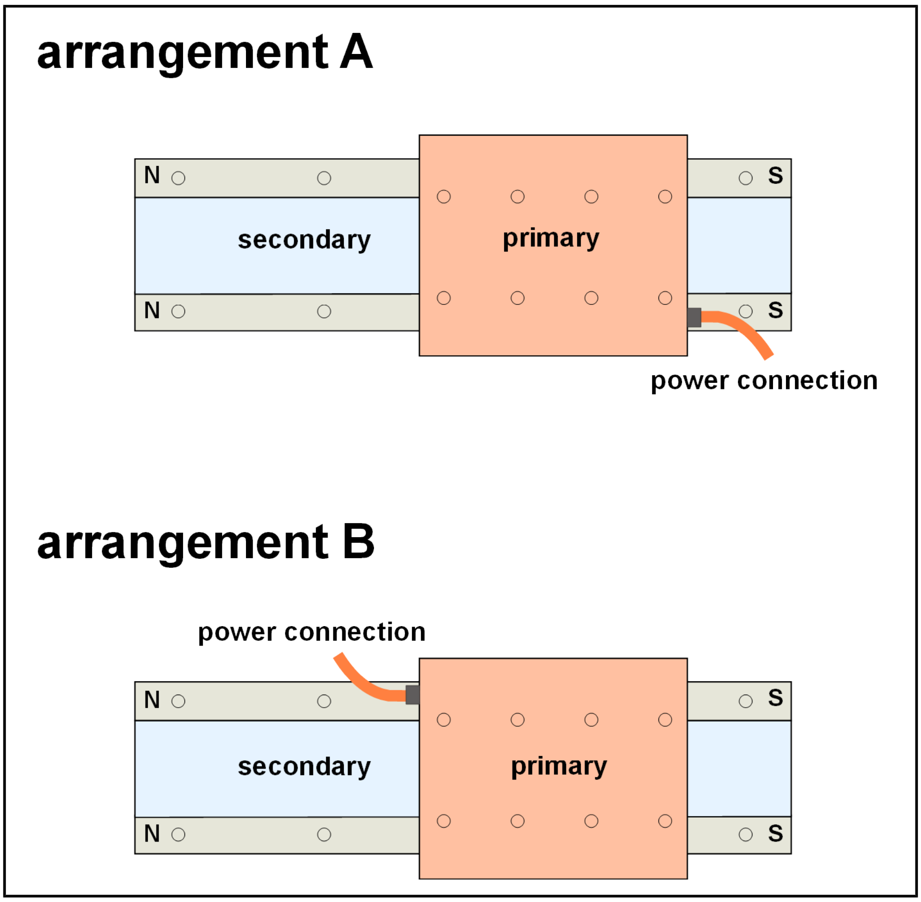



*Fig. 14-10: Possible arrangements between primary and secondary part*

| | Arrangement A<br>$k_{mx}$ in mm | Arrangement B<br>$k_{mx}$ in mm |
|---|---|---|
| **Standard encapsulation**frame sizes 040 ... 300 | 68 | 105,5 |
| **Thermal encapsulation** Size 040 ... 300 | 65 | 102,5 |

*Fig. 14-11: Motor constants for commutation adjustment kmx*

**Example 1**, reference ① (see fig. 14-8 "Measuring the relative position between primary and secondary part" on page 236):

d = 100 mm , $k_{mx}$ = 68.0 mm

**P-0-0523 = d - $k_{mx}$** = 100 mm - 68.0 mm = 32 mm

**Example 2**, reference ① (see fig. 14-8 "Measuring the relative position between primary and secondary part" on page 236):

d = 0 mm , $k_{mx}$ = 68.0 mm

**P-0-0523 = d - $k_{mx}$** = 0 mm - 68.0 mm = 68.0 mm

**Example 3**, reference ④ (see fig. 14-8 "Measuring the relative position between primary and secondary part" on page 236):

g = 180 mm , $k_{mx}$ = 68.0 mm , $l_p$ = 540 mm

**P-0-0523 = 37.5 mm - g -** $l_p$ **-** $k_{mx}$ = 37.5 mm -180 mm - 540 mm - 68 mm

P-0-0523 = 750.5 mm

**Activation of Commutation Adjustment Command**

**Prerequisites:**

1. The drive must be in the A0-13 state during the subsequent adjustment procedure (ready for power connection).
2. The position of the primary part and/or the slide must not habe changed since the relative position of the primary part with respect to the secondary part has been measured.

Once the determined value P-0-0523, commutation setting measured value, has been entered, the command P-0-0524, D300 commutation setting command must be started. The commutation offset is calculated in this step. The commutation offset is calculated in this step.

☞ If the drive is in control mode when the command is started, the commutation offset is determined using the current flow method (see method 2).

The command must subsequently be cleared.

## 14.6.3 Method 2: Current Flow Method Manually Activated

This method is used for the following configurations:

☞
- Synchronous linear motors with absolute linear scale. In first-time commissioning, as an alternative of method 1.

1. Adjust the operation mode "Torque-force control"
2. Bring the drive into control (AF).
3. Start the commando via P-0-0524

**WARNING**

**Injuries due to errors in trigger motors and moving elements!**

⇒ Is the drive not accordingly commutated, then the drive must only be switched in operation mode "Torque-force control" in AF.

⇒ Is the drive switched in velocity control or in position control in AF, an uncontrolled axis movement cannot be excepted.

☞ The parameter P-0-0560, commutation adjustment voltage, P-0-0562 and cycle duration can individually be adjusted at initial start-up by the user.

## 14.6.4 Method 3: Current Flow Method Automatically Activated

**Controllers ECODRIVE and DIAX04**

This method is used for the following configurations:

☞
- Synchronous linear motor with incremental length scale in connection with controllers Ecodrive and Diax04

  At initial start-up of the axis, the parameter P-0-0560, commutation adjustment voltage, P-0-0562 and commutation adjustment are automatically determinated and recorded in the drive. At every re-start of the axis, the commutation adjustment is made new to method 3. The parameter values for P-0-0560 and P-0-0562 of the initial start-up serve as initial value for the procedure.

☞ The parameter P-0-0560, commutation adjustment voltage, P-0-0562 and cycle duration can individually be adjusted at initial start-up by the user.

**Controller IndraDrive**

This method is used for the following configurations:

☞

- Synchronous linear motors with incremental length measuring system in connection with INDRADRIVE controllers. At initial start-up of the axis, the parameters P-0-0506, peak value for angle-survey and P-0-0507, test frequency for angle-survey are automatically determinated, if in P-0-506 ”0” is entered. Subsequently, the determined parameters are recorded in the drive-device. At every re-start of the axis, the commutation adjustment is made new to method 3. The parameter values for P-0-0506 and P-0-0507 of the initial start-up serve as initial value for the procedure.

☞ The parameters P-0-0506, peak value for angle-survey and P-0-507, test frequency for angle-survey can individually be adjusted at initial start-up by the user.

## 14.7 Setting and Optimizing the Control Loop

### 14.7.1 General Sequence

The control loop settings in a digital drive controller are significant to the characteristics of the servo axis. The control loop structure consists of a cascaded position, velocity and current controller. The corresponding mode defines the active controllers.

☞ Defining the control loop settings requires the corresponding expertise.

The procedure used for optimizing the control loops (current, velocity and position controllers) of linear direct drives corresponds to the one used for rotary servo drives. At linear drives are only the adjustment limits higher.

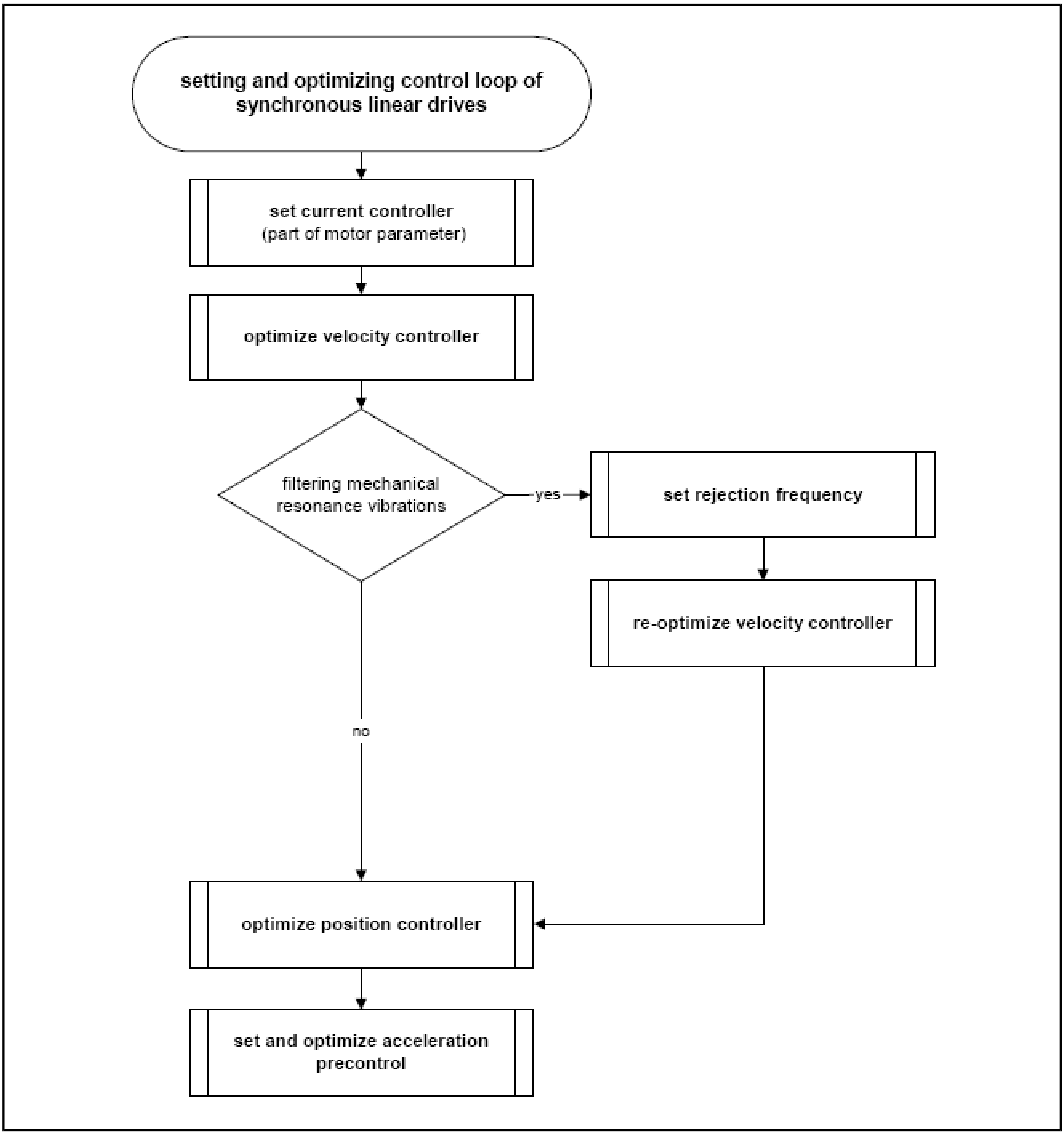



*Fig. 14-12: Setting and optimizing the control loop of synchronous linear drives.*

☞ Use the functional description of the drive controller for more additional information

**Automatic Control Loop Setting**

Drive controllers of the EcoDrive03 series are able to perform automatic control loop adjustment.

**Filtering Mechanical Resonance Vibrations**

Digital drives from Rexroth are able to provide a narrow-band suppression of vibrations that are produced due to the power train between motor and mechanical axis system. This results in increased drive dynamic at a good stability.

The position or velocity feedback in the closed control loop excites the mechanical system of the slide that is moved by the linear drive to perform mechanical vibrations. This behavior, known as ”Two-masses vibration”, is mainly in the frequency range between 400 and 800 Hz. It depends on the rigidity of the mechanical system and the spatial expansion of the system.

In most cases, this ”Two-masses vibration” has a clear resonant frequency that can selectively be suppressed by a rejection filter in the drive.

When the mechanical resonant frequency is suppressed, improving the dynamic properties of the velocity control loop and of the position control loop with may be possible, compared with close-loop operation without the rejection filter.

This leads to an increased profile accuracy and to smaller cycle times for positioning processes at a sufficient distance to the stability limit.

Rejection frequency and bandwidth of the filter can be selected. The highest attenuation takes effect on the rejection frequency. The bandwith defines the frequency range at which the attenuation is less than –3 dB. A higher bandwidth leads to less attenuation of the rejection frequency!

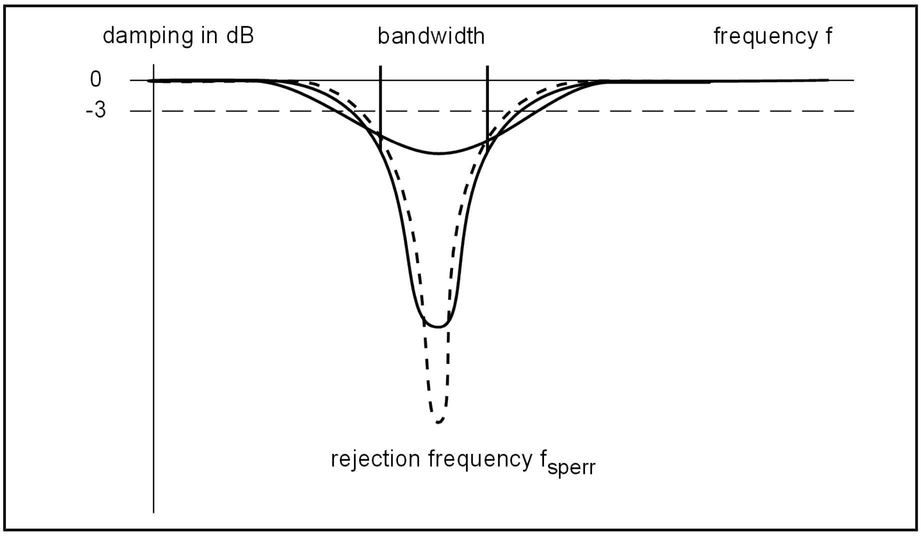



*Fig. 14-13: Amplitude frequency curve rejection filter vs. bandwidth, qualitative*

## 14.7.2 Parameter Value Assignments and Optimization of Gantry Axes

### General Information

**Prerequisites:**

- The parameter settings of the axes are identical
- Parallelism of the guides of the Gantry axes
- Parallelism of the linear scale
- In the controller, the axes are registered as individual axes

☞ Drive-internal axis error compensation procedures can be used for compensating the misalignments between two linear scales as or the mechanical system. Please refer to the corresponding description of functions of the drive controller for a description of the operational principle and the parameter settings.

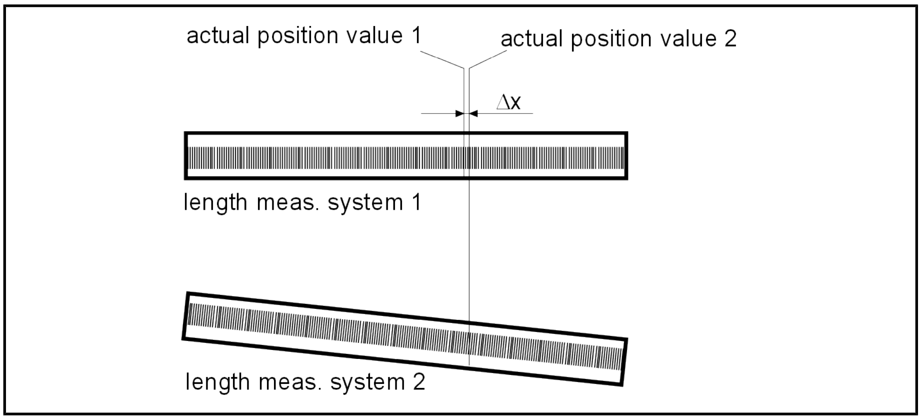



*Fig. 14-14: Possible misalignment with the linear scale of a Gantry axes*

## Parameter settings

When using Gantry axes, your must ensure that the parameter settings of the following parameters are identical:

- Motor parameters
- Polarity parameters for force, velocity and position
- Control loop parameters

We have:

$$k_{v1} = k_{v2}$$

$$k_{p1} = k_{p2}$$

$k_v$ Position controller kv-factor S-0-0104
$k_p$ Velocity controller proportional gain S-0-0100

*Fig. 14-15: Proportional gains in the position and velocity control loop of both axes.*

**Velocity Controller Integral Time (Integral Part)**

The following possibilities must be taken into account for the velocity controller integral time (integral part):

| | Possibility 1 | Possibility 2 | Possibility 3 | Possibility 4 |
|---|---|---|---|---|
| Alignment of length linear scale and guides | ideal | not ideal | not ideal | not ideal |
| Integral Part | in both axes | in both axes | in one axis only | in no axis |
| Behaviour of the axes | Since both motors follow the position command value ideally, there will not be a distortion of the mechanical system | Both axes work against each other until there is an equalization via the mechanical coupling or until the maximum current of one or both drive controller(s) has been reached and a control effect is no longer possible. | The axis without integral-part permits a continuous position offset. The size of the position offset depends on the rigidity of the mechanical coupling of both axes and of the proportional gains in the position and velocity control loop. | Both axes permit a continuous position offset. The size of the position offset depends on the proportional gains in the position and velocity control loop. |

*Fig. 14-16: Parameterization of the velocity controller integral time S-0-0101 for Gantry-axes.*

**Optimization**

The previously described procedure must be followed for optimizing the position and velocity loop.

> ☞ Any parameter modifications that are made during the optimization of Gantry axes must always be made in both axes simultaneously. If this is not possible, the parameter changes should be made during optimization in smaller subsequent steps in both axes.

## 14.7.3 Estimating the Moved Mass Using a Velocity Ramp

Often, the exact moving mass of the machine slide is not known. Determining this mass can be made difficult by moving parts, additionally mounted parts, etc.

The procedure explained below permits the moving axes mass to be estimated on the basis of a recorded velocity ramp. This permits, for example, the acceleration capability of the axis to be estimated.

**Preparation**

This procedure requires the oscillographic recording of the following parameters:

- S-0-0040, actual velocity value
- S-0-0080, torque/force command value

You can either use an oscilloscope or the oscilloscope function of the drive in conjunction with DriveTop or NC.

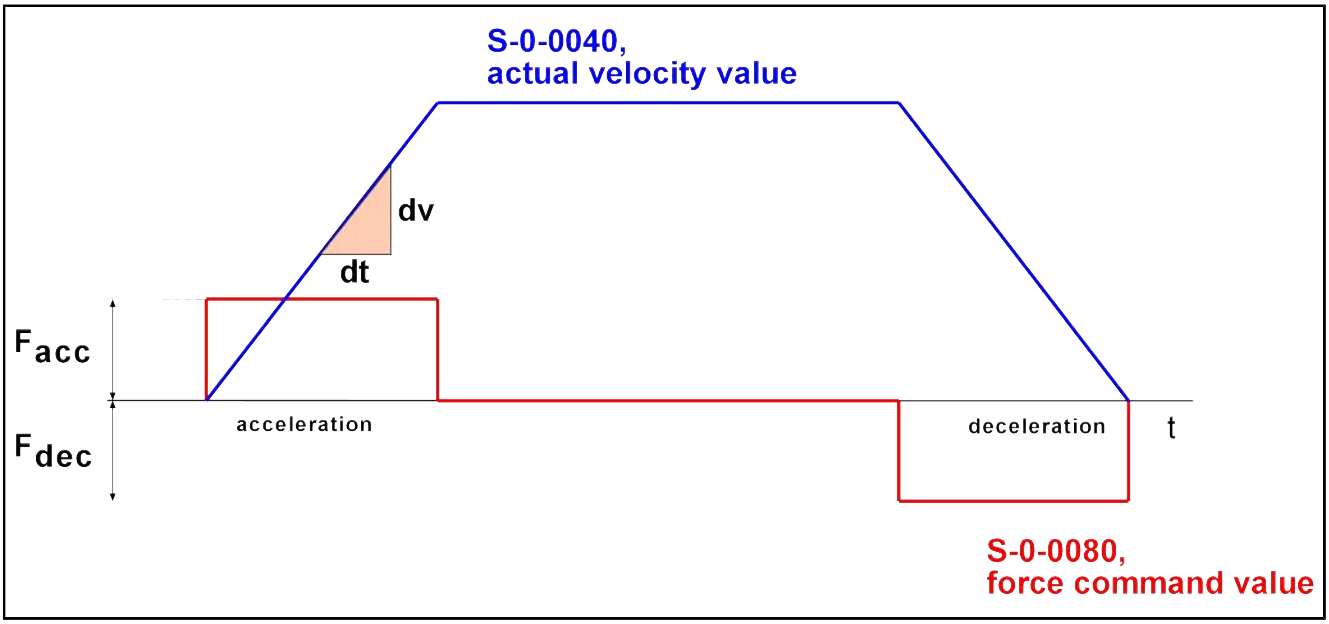



*Fig. 14-17: Oscillogram of velocity and force*

$$m = 30 \cdot F_{dN} \cdot \left( \frac{F_{ACC} + F_{DEC}}{100\%} \right) \cdot \frac{\Delta t}{\Delta v}$$

| | |
|---|---|
| m | Moved axis mass in kg |
| $F_{dN}$ | Continuous nominal force of the motor in N |
| $F_{ACC}$ | Force command value during acceleration in % |
| $F_{DEC}$ | Force command value during braking in % |
| $\Delta v$ | Velocity change during constant acceleration in m/min |
| $\Delta t$ | Time change during constant acceleration in s |

*Fig. 14-18: Determining the moved axis mass on the basis of a recorded velocity ramp*

**Prerequisites:**

1. Correct parameter settings of the rated motor current (basis of representation S-0-0080)
2. Frictional force not directional
3. Recording of Δv and Δt at constant acceleration
4. Do not perform at maximum motor force to avoid non-linearities

☞ Due to possible direction-related force variations, this procedure cannot or only conditionally be used for vertical axes.

# 14.8 Maintenance and Check of Motor Components

## 14.8.1 General Information

The motor components of IndraDyn L do not need any maintenance. Due to external influence, the motor components can be damaged during operation. There should be a preventive maintenance of the linear motor components within the service intervals of the machine or system.

## 14.8.2 Check of Motor and Auxiliary Components

The following points should be observed and if necessary restored during the preventive check of motor and auxiliary components:

- Noticeable sound during operation
- Scratches on primary and secondary part
- Dirt (e.g. shavings, swarfs, grease by guides etc.) within the air gap between primary and secondary part

  Check the functionality of the protection measures and change them if necessary! See also chapter 9.3.4 "Protection of the Motor Installation Space" on page 103.
- Tightness of liquid cooling, hoses and connections
- State of power and encoder cables in a drag chain.
- State of linear scale (e.g. soiled)
- State of guides (e.g. deterioration of linear guides)

## 14.8.3 Electrical Check of Motor Components

The electrical defect of a primary part can be checked by measuring electrical characteristics. The following variables are relevant:

- Resistance between motor connecting wires 1-2, 2-3 and 1-3
- Inductance between motor connecting wires 1-2, 2-3 and 1-3

- Insulation resistance between motor connecting wired and guides

**Resistance and Inductance**

The measured values of resistance and inductance can be compared with the values specified in Chapter 4 ”Technical Data”. The individual values of resistance and inductance measured between the connections 1-2, 2-3 and 1-3 should be identical – within a tolerance of ± 5 %. There can be a phase short circuit, a fault between windings, or a short circuit to ground if one or more values differ significantly. If so, the primary part must be exchanged.

**Isolation Resistance**

The insulation resistance – measured between the motor connecting leads and ground – should be at least 1 MΩ (MegaOhm) The primary part must be replaced in this case.

---

☞ If there are and doubts during the electrical verification, please consult Rexroth Service.

---

# 15 Appendix

## 15.1 Recommended Suppliers of Additional Components

### 15.1.1 Length Measuring System

Bosch Rexroth AG
Maria-Theresien-Str. 23
97816 Lohr am Main, Germany
Internet: http://www.boschrexroth.com

**DR. JOHANNES HEIDENHAIN GmbH**
Dr.-Johannes-Heidenhain-Straße 5
83301 Traunreut, Germany
Internet: http://www.heidenhain.de

**Renishaw GmbH**
Karl-Benz Strasse 12
72124 Pliezhausen, Germany
Internet: http://www.renishaw.com

### 15.1.2 Linear Scales

Bosch Rexroth AG
Maria-Theresien-Str. 23
97816 Lohr am Main, Germany
Internet: http://www.boschrexroth.com

### 15.1.3 Energy Chains

**igus GmbH**
Spicher Straße 1a
51147 Cologne, Germany
Internet: http://www.igus.de

**KABELSCHLEPP GMBH**
Marienborner Straße 75
57074 Siegen, Germany
Internet: http://www.kabelschlepp.de

### 15.1.4 Cooling Aggregate

**SCHWÄMMLE GmbH & Co KG**
Dieselstraße 12-14
71546 Aspach, Germany
Internet: http://www.schwaemmle-gmbh.de

**Universal Hydraulik GmbH**
Siemensstraße 33
61267 Neu-Anspach, Germany
Internet: http://www.universalhydraulik.com

### 15.1.5 Coolant Additives

**NALCO Deutschland GmbH**
Plankstr. 26
71691 Freiberg/Neckar, Germany
Fax +49(0)7141-703-239
e-mail: slund@nalco.com

### 15.1.6 Coolant Hose

**Polyflex AG**
Dorfstaße 49
5430 Wettingen, Switzerland
Internet: http://www.polyflex.ch

**igus GmbH**
Spicher Straße 1a
51147 Cologne, Germany
Internet: http://www.igus.de

Bosch Rexroth AG
Maria-Theresien-Str. 23
97816 Lohr am Main, Germany
Internet: http://www.boschrexroth.com

### 15.1.7 Axis Cover Systems

**Möller Werke GmbH**
Kupferhammer
33649 Bielefeld, Germany
Internet: http://www.moellerflex.de

**HCR-Heinrich Cremer GmbH**
Oppelner Str. 37
41169 Moenchengladbach, Germany
Internet: http://hcr.connection-net.de/deutsch/index.html

**Gebr. HENNIG GmbH**
P. O. Box 1137
85729 Ismaning, Germany
Internet: http://www.hennig-gmbh.de

## 15.1.8 End Position Cushioning

**ACE Stoßdämpfer GmbH**
P. O. Box 1510
40740 Langenfeld, Germany
Internet: http://www.ace-ace.de

Bosch Rexroth AG
Maria-Theresien-Str. 23
97816 Lohr am Main, Germany
Internet: http://www.boschrexroth.com

**Metal Braid Shock Absorbers**

**Rhodius GmbH**
Treuchlinger Str. 23
91781 Weißenburg, Germany
Internet: http://www.rhodius.com

## 15.1.9 Clamping Elemens for Linear Scales

Bosch Rexroth AG
Maria-Theresien-Str. 23
97816 Lohr am Main, Germany
Internet: http://www.boschrexroth.com

## 15.1.10 External Mechanical Brakes

**Kendrion Binder Magnete GmbH**
Mönchweilerstr. 1
78048 Villingen-Schwenningen, Germany
Internet: http://www.kendrion-electromagnetic.com

**Ortlinghaus-Werke GmbH**
Kenkhauser Str. 125
42929 Wermelskirchen, Germany
Internet: http://www.ortlinghaus.com

### 15.1.11 Weight Compensation Systems

**Pneumatic**

**Ross Europa GmbH**
Robert-Bosch-Str. 2
63225 Langen, Germany
Internet: http://www.rosseuropa.com

**Hydraulic**

Bosch Rexroth AG
Maria-Theresien-Str. 23
97816 Lohr am Main, Germany
Internet: http://www.boschrexroth.com

### 15.1.12 Wiper

**Hunger DFE GmbH Dichtungs- und Führungselemente**
Alfred-Nobel Str. 26
97080 Würzburg. Germany
Internet: http://www.hunger-dichtungen.de

**HME Dichtungssysteme**
Richthofenstr. 31
86343 Königsbrunn, Germany
Internet: http://www.hme-seals.de

# 15.2 Enquiry Form for Linear Drives

| | | |
|---|---|---|
| Bosch Rexroth<br>Fax:<br><br>Contact person: | ..........................................................<br><br>.......................................................... | Date: ........................ |

**1. Information for the user**

| | | | |
|---|---|---|---|
| Company | ................................................ | Name | ...................................................... |
| Street | ................................................ | Department | ...................................................... |
| Zip Code | ................................................ | Phone | ...................................................... |
| Place | ................................................ | Fax | ...................................................... |
| | | Email | ...................................................... |

| | | | | |
|---|---|---|---|---|
| Requesting to: | O Recall | O Drive dimensioning | O Offer | O ............................................. |

**2. General information on use**

| | |
|---|---|
| Sector | O Machine Tools O Automation O Packaging O Printing<br>O ........................................................................................... |
| Type of use | ...........................................................................................<br>........................................................................................... |
| Designation of the Axis | ........................................................................................... |
| Axis Grouping | O Single axis O Grouping of .......... axis within the machine<br>O only linear drives O rotative and linear drives |
| Quantity | ......................... per year |

**3. Mechanical and cinematic requirements**

| | | | |
|---|---|---|---|
| Installation position | O Horizontal | O Vertical | O Slant, axis angle: ..........degrees |
| Moved motor component | O Primary part moves | | O Secondary part moves |
| Moved mass | ..................... kg (incl. guides, power feeders, etc.) | | |
| Maximum velocity | ................... m/min | Maximum acceleration | ..................... m/s² |
| Base force | ..................... N (friction, energy supply, etc. ) | | |
| Machining force | ..................... N (detailed specifications see point 5) | | |

*Fig. 15-1: Enquiry form (Sheet 1/4)*

Appendix

| | |
|---|---|
| 4. Ambient conditions | |
| Ambient temperature | ..................... °C |
| Machined material | 0 Steel / cast iron 0 Light metal 0 Plastic 0 Wood<br>0 Other:...................................... 0 None(only handling) |
| Dirt and aggressive media | 0 Chips 0 Dust<br>0 Oil or lubricants: ..................................................................<br>0 Other: ................................................................................ |
| Protection of motor components | 0 Bellows 0 Telescopic cover 0 Wiper on secondary<br>0 Other:<br>........................................................................................ |
| 5. Thermal conditions and cooling | |
| 0 Liquid cooling | Coolant and additives: ..................................................................... |
| | Inlet temperature, minimum: ............°C maximum: .............°C |
| | Max. flow quantity: .........l/min Max. system pressure: .........bar |
| | Maximum heating of the machine structure: .......... K 0 Not relevant |
| | Maximum coolant temperature rise: ..................... K 0 Not relevant |
| | Additional cooling at machine 0 Yes 0 No |
| 0 Air cooling, natural convection | (Reducing the continuous forces to approximately 25 %) |
| 6. Drive and Control | |
| Drive series | 0 ECODRIVE03 0 DIAX04 0 IndraDrive |
| Main voltage | 0 1 x 230 V 0 3 x 400 V 0 3 x 480 V 0 .............................. |
| Drive interface / bus system | 0 SERCOS interface 0 ANALOG ±10V 0 Parallel interface<br>0 Profibus 0 Interbus 0 CANopen 0 DeviceNet 0 PWM<br>0 ........................................................................................................... |
| Control | 0 ..............................................:.............................................................. |
| 7. Linear scale | |
| Measuring principle and interface | 0 absolut ENDAT<br>0 incremental, sine signals 1 $V_{ss}$<br>0 incremental, sine signals 1 $V_{ss}$, distance-encoded reference marks |
| Model | 0 open buides 0 encapsulated 0 integradted in linear |
| Positioning accurary | ........................ µm |

*Fig. 15-2: Enquiry form (Sheet 2/4)*

| 8. Motion profile | |
|---|---|
| Specification of motion profile | 0 Not required, drive selection data exist (see 8.1)<br>0 Strokes, positioning and idle times, maximum velocity and acceleration as specified under item 3 (see 8.2)<br>0 Sketch of velocity profile v(t) and process forces $F_P(t)$ (see 8.2 and 8.3)<br>0 Operating phases and duty cycles (see 8.4)<br>0 Equation of motion for s(t) and / or v(t) (see 8.5)<br>0 s(t) and / or v(t) can ve specified in digital form:<br>0 MathCad 0 Excel 0 ASCII 0 ........................ |

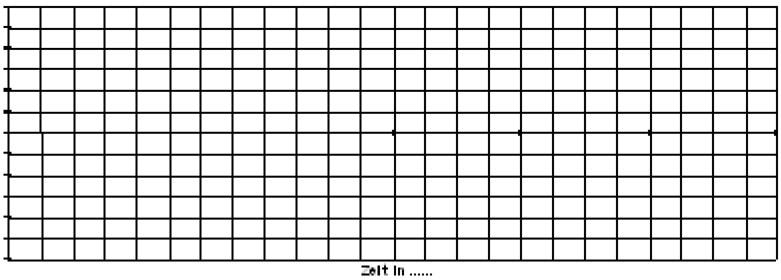
8.1 Data for motion selection exists:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| $F_{max}$: | ............ N | $F_{EFF}$ / $F_{dN}$: | ............ N | $v_{Fmax}$: | ............ m/min | $v_{max}$: | ............ m/min |

8.2 Specification of strokes, position and idle times

| Stroke | Travel | Positioning time | Idle time | Stroke | Travel | Positioning time | Idle time |
|---|---|---|---|---|---|---|---|
| 1 | | | | 8 | | | |
| 2 | | | | 9 | | | |
| 3 | | | | 10 | | | |
| 4 | | | | 11 | | | |
| 5 | | | | 12 | | | |
| 6 | | | | 13 | | | |
| 7 | | | | 14 | | | |

8.3 Sketch of velocity profile and process forces



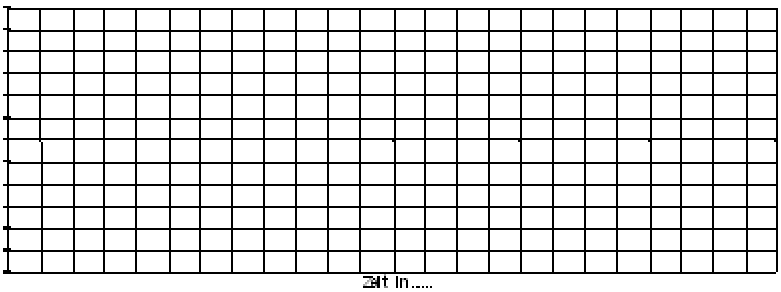




*Fig. 15-3: Enquiry form (Sheet 3/4)*

| 8.4 Specification of operating phases and related duty cycle | | |
|---|---|---|
| | $ED_i$ | Force $F_i$ |
| Acceleration, deceleration at ............m/s² | ............ % | ............ N |
| Acceleration, deceleration at ............m/s² and machining | ............ % | ............ N |
| Rapid traverse at v = constant = ........... m/min | ............ % | ............ N |
| Machining at v = .......... m/min | ............ % | ............ N |
| Standstill with machining | ............ % | ............ N |
| Standstill without machining | ............ % | ............ N |
| ........................................................................... | ............ % | ............ N |
| Total: | 100 % | |

| 8.5 Equation of motion for s(t) or v(t) | |
|---|---|
| Equation of motion,<br>e.g.: $s(t) = r \cdot \sin(\omega \cdot t)$ | |
| Explanation: | |

| 9. Miscellaneous/comments/sketches |
|---|
| .................................................................................................................................................... |
| .................................................................................................................................................... |
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*Fig. 15-4: Enquiry form (Sheet 4/4)*

# 16 Service and Support

## 16.1 Helpdesk

Our service helpdesk at our headquarters in Lohr, Germany, will assist you with all kinds of inquiries.

Contact us:

- By phone through the Service Call Entry Center

  Monday to Friday: 7:00 am - 6:00 pm Central European Time

  **+49 (0) 9352 40 50 60**
- By fax

  **+49 (0) 9352 40 49 41**
- By e-mail: service.svc@boschrexroth.de

## 16.2 Service Hotline

Out of helpdesk hours please contact our German service department directly:

**+49 (0) 171 333 88 26**

or

**+49 (0) 172 660 04 06**

Hotline numbers for other countries can be found in the addresses of each region on the Internet (see below).

## 16.3 Addresses

For the current addresses of our sales and service offices, see

http://www.boschrexroth.com

On this website you will find additional notes regarding service, maintenance (e.g. delivery addresses) and training.

Outside Germany please contact our sales/service office in your area first.

## 16.4 Helpful Information

For quick and efficient help please have the following information ready:

- Detailed description of the fault and the circumstances
- Information on the type plate of the affected products, especially type codes and serial numbers
- Your phone and fax numbers and e-mail address, so we can contact you in case of questions

# Index

Index

# Notes

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Bosch Group

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