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Synchronous Linear Motors MLF

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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 rotary 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

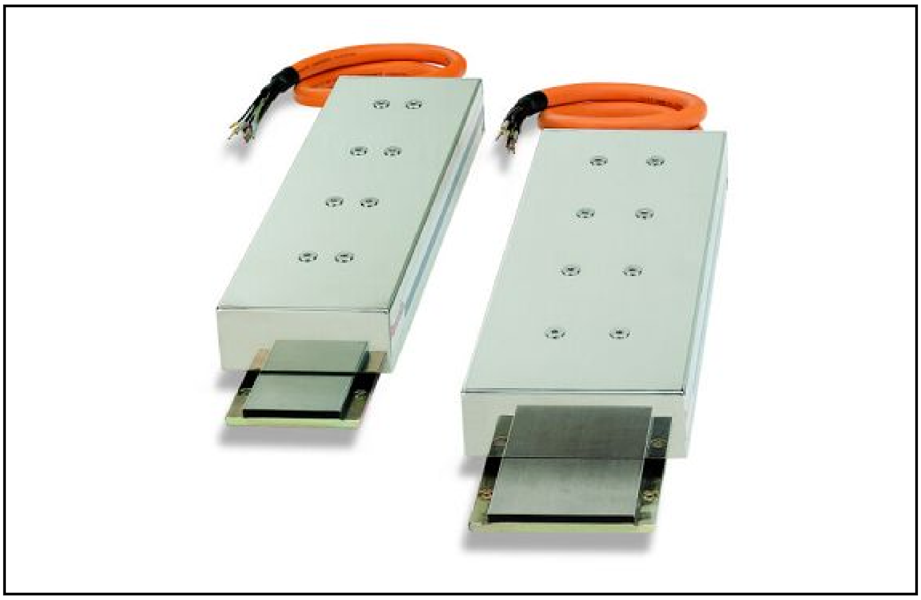

Fig. 1-1: Illustration example IndraDyn L

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

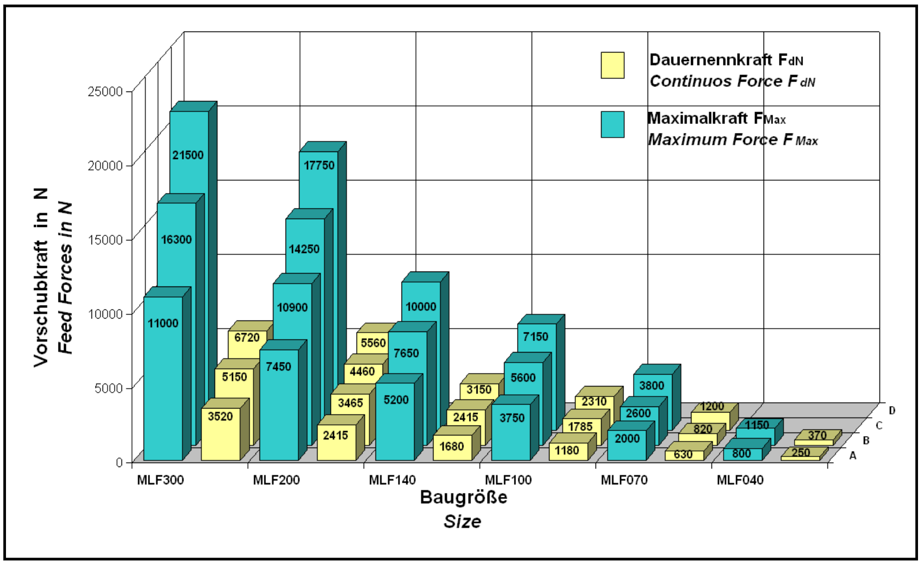

Fig.1-2: Performance spectrum IndraDyn L motors

1.2 About this Documentation

1.2.1 Document Structure

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

<table>
<tr><th>Chapter</th><th>Title</th><th colspan="4">Content</th></tr>
<tr><td>1</td><td>Introduction</td><td colspan="4">Product presentaion / Notes regarding reading</td></tr>
<tr><td>2</td><td>Important Instructions on Use</td><td colspan="4" rowspan="2">Important Safety Instructions</td></tr>
<tr><td>3</td><td>Safety</td></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

To plan the drive-systems with MLF motors, it is possible that you need additional documentation referring the used devices. Rexroth provides the complete product documentation in PDF format in the following Bosch Rexroth media directory:

http://www.boschrexroth.com/various/utilities/mediadirectory/index.jsp

1.2.3 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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1.2.4 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 references to manufacturers, please refer to chapter 14 "Appendix" on page 261.

1.2.5 Your Feedback

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

Please send your remarks to:

Bosch Rexroth AG

Dept. DC-IA/EDM3 (fs, mb)

Buergermeister-Dr.-Nebel-Strasse 2

97816 Lohr am Main, Germany

Email: dokusupport@boschrexroth.de

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.

⚠ WARNING **Improper product handling may result in personal injury and property damage!**

Only use the products as intended. If they are not used as intended, situations may arise resulting in personal injuries and property damage.

☞ 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 may be made. Software products may not be decompiled; their source codes may not be modified.
- Damaged or improperly working products may 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 may only be used with the accessories specified in this documentation. Components that are not explicitly mentioned may neither be attached nor connected. The same is applicable for cables and lines.
- Operation is only allowed 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 controller 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 be absolutely sure to comply with the instructions given in the general safety instructions!

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

Property right of third party

When compositing and using each components of Bosch Rexroth, absolutely observe the property right of third party. For any violation of such rights, the customer is liable for the resulting damage.

3 Safety Instructions for Electric Drives and Controls

3.1 Definition of Terms

Component An installation consists of several devices or systems interconnected for a defined purpose and on a defined site which, however, are not intended to be placed on the market as a single functional unit.

Electric Drive System An electric drive system comprises all components from mains supply to motor shaft; this includes, for example, electric motor(s), motor encoder(s), supply units and drive controllers, as well as auxiliary and additional components, such as mains filter, mains choke and the corresponding lines and cables.

User A user is a person installing, commissioning or using a product which has been placed on the market.

User Documentation Application documentation comprises the entire documentation used to inform the user of the product about the use and safety-relevant features for configuring, integrating, installing, mounting, commissioning, operating, maintaining, repairing and decommissioning the product. The following terms are also used for this kind of documentation: User Guide, Operation Manual, Commissioning Manual, Instruction Manual, Project Planning Manual, Application Manual, etc.

Electrical Equipment Electrical equipment encompasses all devices used to generate, convert, transmit, distribute or apply electrical energy, such as electric motors, transformers, switching devices, cables, lines, power-consuming devices, circuit board assemblies, plug-in units, control cabinets, etc.

Device A device is a finished product with a defined function, intended for users and placed on the market as an individual piece of merchandise.

Manufacturer The manufacturer is an individual or legal entity bearing responsibility for the design and manufacture of a product which is placed on the market in the individual's or legal entity's name. The manufacturer can use finished products, finished parts or finished elements, or contract out work to subcontractors. However, the manufacturer must always have overall control and possess the required authority to take responsibility for the product.

Component A component is a combination of elements with a specified function, which are part of a piece of equipment, device or system. Components of the electric drive and control system are, for example, supply units, drive controllers, mains choke, mains filter, motors, cables, etc.

Machine A machine is the entirety of interconnected parts or units at least one of which is movable. Thus, a machine consists of the appropriate machine drive elements, as well as control and power circuits, which have been assembled for a specific application. A machine is, for example, intended for processing, treatment, movement or packaging of a material. The term "machine" also covers a combination of machines which are arranged and controlled in such a way that they function as a unified whole.

Product Examples of a product: Device, component, part, system, software, firmware, among other things.

Project Planning Manual A project planning manual is part of the application documentation used to support the sizing and planning of systems, machines or installations.

Qualified Personnel In terms of this application documentation, qualified persons are those persons who are familiar with the installation, mounting, commissioning and operation of the components of the electric drive and control system, as well as with the hazards this implies, and who possess the qualifications their work requires. To comply with these qualifications, it is necessary, among other things,

1) to be trained, instructed or authorized to switch electric circuits and devices safely on and off, to ground them and to mark them

2) to be trained or instructed to maintain and use adequate safety equipment

3) to attend a course of instruction in first aid

Control System A control system comprises several interconnected control components placed on the market as a single functional unit.

3.2 General Information

3.2.1 Using the Safety Instructions and Passing Them on to Others

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

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

Improper use of these components, failure to follow the safety instructions in this document or tampering with the product, including disabling of safety devices, could result in property damage, injury, electric shock or even death.

3.2.2 Requirements for Safe Use

Read the following instructions before initial commissioning of the components of the electric drive and control system in order to eliminate the risk of injury and/or property damage. You must follow these safety instructions.

- Bosch Rexroth is not liable for damages resulting from failure to observe the safety instructions.
- Read the operating, maintenance and safety instructions in your language before commissioning. If you find that you cannot completely understand the application documentation in the available language, please ask your supplier to clarify.
- Proper and correct transport, storage, mounting and installation, as well as care in operation and maintenance, are prerequisites for optimal and safe operation of the component.
- Only qualified persons may work with components of the electric drive and control system or within its proximity.
- Only use accessories and spare parts approved by Bosch Rexroth.
- Follow the safety regulations and requirements of the country in which the components of the electric drive and control system are operated.
- Only use the components of the electric drive and control system in the manner that is defined as appropriate. See chapter "Appropriate Use".
- The ambient and operating conditions given in the available application documentation must be observed.
- Applications for functional safety are only allowed if clearly and explicitly specified in the application documentation "Integrated Safety Technolo-

gy". If this is not the case, they are excluded. Functional safety is a safety concept in which measures of risk reduction for personal safety depend on electrical, electronic or programmable control systems.

- The information given in the application documentation with regard to the use of the delivered components contains only examples of applications and suggestions.

  The machine and installation manufacturers must

  – make sure that the delivered components are suited for their individual application and check the information given in this application documentation with regard to the use of the components,
  – make sure that their individual 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 allowed once it is sure that the machine or installation in which the components are installed complies with the national regulations, safety specifications and standards of the application.
- Operation is only allowed 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 application documentation.

  The machine or installation manufacturer is responsible for compliance with the limit values as prescribed in the national regulations.
- The technical data, connection and installation conditions of the components are specified in the respective application documentations and must be followed at all times.

National regulations which the user must take into account

- European countries: In accordance with 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)

3.2.3 Hazards by Improper Use

- High electrical voltage and high working current! Danger to life or serious injury by electric shock!
- High electrical voltage by incorrect connection! Danger to life or injury by electric shock!
- Dangerous movements! Danger to life, serious injury or property damage by unintended motor movements!
- Health hazard for persons with heart pacemakers, metal implants and hearing aids in proximity to electric drive systems!

- Risk of burns by hot housing surfaces!
- Risk of injury by improper handling! Injury by crushing, shearing, cutting, hitting!
- Risk of injury by improper handling of batteries!
- Risk of injury by improper handling of pressurized lines!

3.3 Requirements for Safe Use

3.3.1 Protection Against Contact with Electrical Parts and Housings

☞ This section concerns components of the electric drive and control system with voltages of **more than 50 volts**.

Contact with parts conducting voltages above 50 volts can cause personal danger and electric shock. When operating components of the electric drive and control system, it is unavoidable that some parts of these components conduct dangerous voltage.

High electrical voltage! Danger to life, risk of injury by electric shock or serious injury!

- Only qualified persons are allowed to operate, maintain and/or repair the components of the electric drive and control system.
- Follow the general installation and safety regulations when working on power installations.
- Before switching on, the equipment grounding conductor must have been permanently connected to all electric components in accordance with the connection diagram.
- Even for brief measurements or tests, operation is only allowed if the equipment grounding conductor has been permanently connected to the points of the components provided for this purpose.
- Before accessing electrical parts with voltage potentials higher than 50 V, you must disconnect electric components from the mains or from the power supply unit. Secure the electric component from reconnection.
- With electric components, observe the following aspects:

  Always wait **30 minutes** after switching off power to allow live capacitors to discharge before accessing an electric component. Measure the electrical voltage of live parts before beginning to work to make sure that the equipment is safe to touch.
- Install the covers and guards provided for this purpose before switching on.
- Never touch electrical connection points of the components while power is turned on.
- Do not remove or plug in connectors when the component has been powered.
- Under specific conditions, electric drive systems can be operated at mains protected by residual-current-operated circuit-breakers sensitive to universal current (RCDs/RCMs).

- Secure built-in devices from penetrating foreign objects and water, as well as from direct contact, by providing an external housing, for example a control cabinet.

High housing voltage and high leakage current! Danger to life, risk of injury by electric shock!

- Before switching on and before commissioning, ground or connect the components of the electric drive and control system to the equipment grounding conductor at the grounding points.
- Connect the equipment grounding conductor of the components of the electric drive and control system permanently to the main power supply at all times. The leakage current is greater than 3.5 mA.
- Establish an equipment grounding connection with a copper wire of a cross section of at least 10 mm^2 (8 AWG) or additionally run a second equipment grounding conductor of the same cross section as the original equipment grounding conductor.

3.3.2 Protective Extra-Low Voltage as Protection Against Electric Shock

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

On components of an electric drive and control system provided by Bosch Rexroth, all connections and terminals with voltages between 5 and 50 volts are PELV ("Protective Extra-Low Voltage") systems. It is allowed to connect devices equipped with basic insulation (such as programming devices, PCs, notebooks, display units) to these connections.

Danger to life, risk of injury by electric shock! High electrical voltage by incorrect connection!

If extra-low voltage circuits of devices containing voltages and circuits of more than 50 volts (e.g., the mains connection) are connected to Bosch Rexroth products, the connected extra-low voltage circuits must comply with the requirements for PELV ("Protective Extra-Low Voltage").

3.3.3 Protection Against Dangerous Movements

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

- Improper or wrong wiring or cable connection
- Operator errors
- Wrong input of parameters before commissioning
- Malfunction of sensors and encoders
- Defective components
- Software or firmware errors

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

The monitoring functions in the components of the electric drive and control system will normally be sufficient to avoid malfunction in the connected drives. Regarding personal safety, especially the danger of injury and/or property 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.

Dangerous movements! Danger to life, risk of injury, serious injury or property damage!

A **risk assessment** must be prepared for the installation or machine, with its specific conditions, in which the components of the electric drive and control system are installed.

As a result of the risk assessment, the user must provide for monitoring functions and higher-level measures on the installation side for personal safety. The safety regulations applicable to the installation or machine must be taken into consideration. Unintended machine movements or other malfunctions are possible if safety devices are disabled, bypassed or not activated.

To avoid accidents, injury and/or property damage:

- Keep free and clear of the machine's range of motion and moving machine parts. Prevent personnel from accidentally entering the machine's range of motion by using, for example:
  - Safety fences
  - Safety guards
  - Protective coverings
  - Light barriers
- Make sure the safety fences and protective coverings are strong enough to resist maximum possible kinetic energy.
- Mount emergency stopping switches in the immediate reach of the operator. Before commissioning, verify that the emergency stopping equipment works. Do not operate the machine if the emergency stopping switch is not working.
- Prevent unintended start-up. Isolate the drive power connection by means of OFF switches/OFF buttons or use a safe starting lockout.
- Make sure that the drives are brought to 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 counterbalancing of the vertical axes.
- The standard equipment **motor holding brake** or an external holding brake controlled by the drive controller is **not sufficient to guarantee personal safety**!
- Disconnect electrical power to the components of the electric drive and control system using the master switch and secure them from reconnection ("lock out") 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 components of the electric drive and control system and their

supply leads. If the use of these devices cannot be avoided, check the machine or installation, at initial commissioning of the electric drive and control system, for possible malfunctions when operating such high-frequency, remote control and radio equipment in its possible positions of normal use. It might possibly be necessary to perform a special electromagnetic compatibility (EMC) test.

3.3.4 Protection Against Magnetic and Electromagnetic Fields During Operation and Mounting

Magnetic and electromagnetic fields generated by current-carrying conductors or permanent magnets of electric motors represent a serious danger to persons with heart pacemakers, metal implants and hearing aids.

Health hazard for persons with heart pacemakers, metal implants and hearing aids in proximity to electric components!

- Persons with heart pacemakers and metal implants are not allowed to enter the following areas:
  - Areas in which components of the electric drive and control systems are mounted, commissioned and operated.
  - Areas in which parts of motors with permanent magnets are stored, repaired or mounted.
- If it is necessary for somebody with a heart pacemaker to enter such an area, a doctor must be consulted prior to doing so. The noise immunity of implanted heart pacemakers differs so greatly 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.

3.3.5 Protection Against Contact With Hot Parts

Hot surfaces of components of the electric drive and control system. Risk of burns!

- Do not touch hot surfaces of, for example, braking resistors, heat sinks, supply units and drive controllers, motors, windings and laminated cores!
- According to the operating conditions, temperatures of the surfaces can be **higher than 60 °C** (140 °F) during or after operation.
- Before touching motors after having switched them off, let them cool down for a sufficient period of time. Cooling down can require **up to 140 minutes**! The time required for cooling down is approximately five times the thermal time constant specified in the technical data.
- After switching chokes, supply units and drive controllers 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, and in accordance with the respective safety regulations, the manufacturer of the machine or installation must take measures to avoid injuries caused by burns in the final application. These measures can be, for example: Warnings at the machine or installation, guards (shieldings or barriers) or safety instructions in the application documentation.

3.3.6 Protection During Handling and Mounting

Risk of injury by improper handling! Injury by crushing, shearing, cutting, hitting!

- Observe the relevant statutory regulations of accident prevention.
- Use suitable equipment for mounting and transport.
- Avoid jamming and crushing by appropriate measures.
- Always use suitable tools. Use special tools if specified.
- Use lifting equipment and tools in the correct manner.
- Use suitable protective equipment (hard hat, safety goggles, safety shoes, safety gloves, for example).
- Do not stand under hanging loads.
- Immediately clean up any spilled liquids from the floor due to the risk of falling!

3.3.7 Battery Safety

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

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 attempt to 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 the electrical parts installed in the devices.
- Only use the battery types specified for the product.

☞ 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 separately from other waste. Observe the national regulations of your country.

3.3.8 Protection Against Pressurized Systems

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

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 (safety goggles, safety shoes, safety gloves, for example).
- Immediately clean up any spilled liquids from the floor due to the risk of falling!

☞ Environmental protection and disposal! The agents (e.g., fluids) used to operate the product might not be environmentally friendly. Dispose of agents harmful to the environment separately from other waste. Observe the national regulations of your country.

3.4 Explanation of Signal Words and the Safety Alert Symbol

The Safety Instructions in the available application documentation contain specific signal words (DANGER, WARNING, CAUTION or NOTICE) and, where required, a safety alert symbol (in accordance with ANSI Z535.6-2006).

The signal word is meant to draw the reader's attention to the safety instruction and identifies the hazard severity.

The safety alert symbol (a triangle with an exclamation point), which precedes the signal words DANGER, WARNING and CAUTION, is used to alert the reader to personal injury hazards.

⚠ DANGER

In case of non-compliance with this safety instruction, death or serious injury **will** occur.

⚠ WARNING

In case of non-compliance with this safety instruction, death or serious injury **could** occur.

⚠ CAUTION

In case of non-compliance with this safety instruction, minor or moderate injury could occur.

NOTICE

In case of non-compliance with this safety instruction, property damage could occur.

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

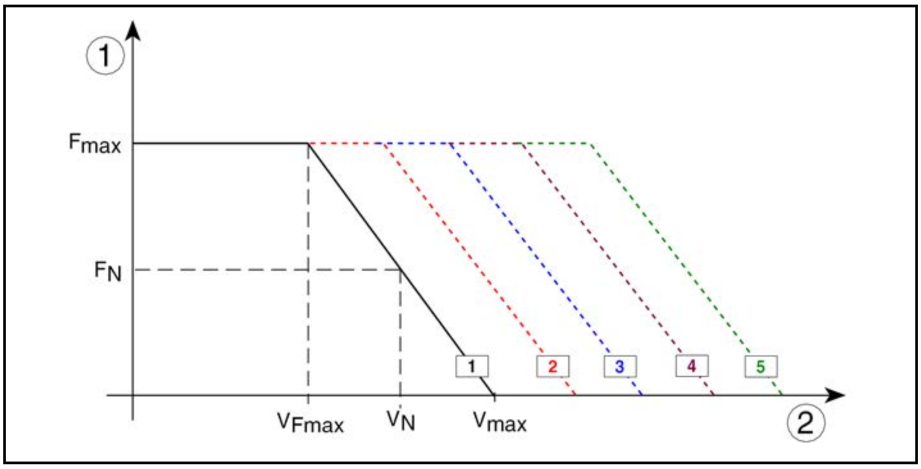
☞ All given data and characteristic curves relate on the following conditions – unless otherwise noted:

- 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.

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.



①	Force [N]
②	Velocity [m/min].
[1]	Average DC bus voltage, unregulated U_{DC} = 540 V
[2]	Average DC bus voltage, unregulated U_{DC} = 600 V
[3]	Average DC bus voltage, unregulated U_{DC} = 650 V
[4]	DC bus voltage, regulated U_{DC} = 650 V
[5]	DC bus voltage, regulated U_{DC} = 750 V

Fig.4-1: Example motor characteristic curve

Technical Data IndraDyn L

☞ The reachable motor force depends on the drive control device 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

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

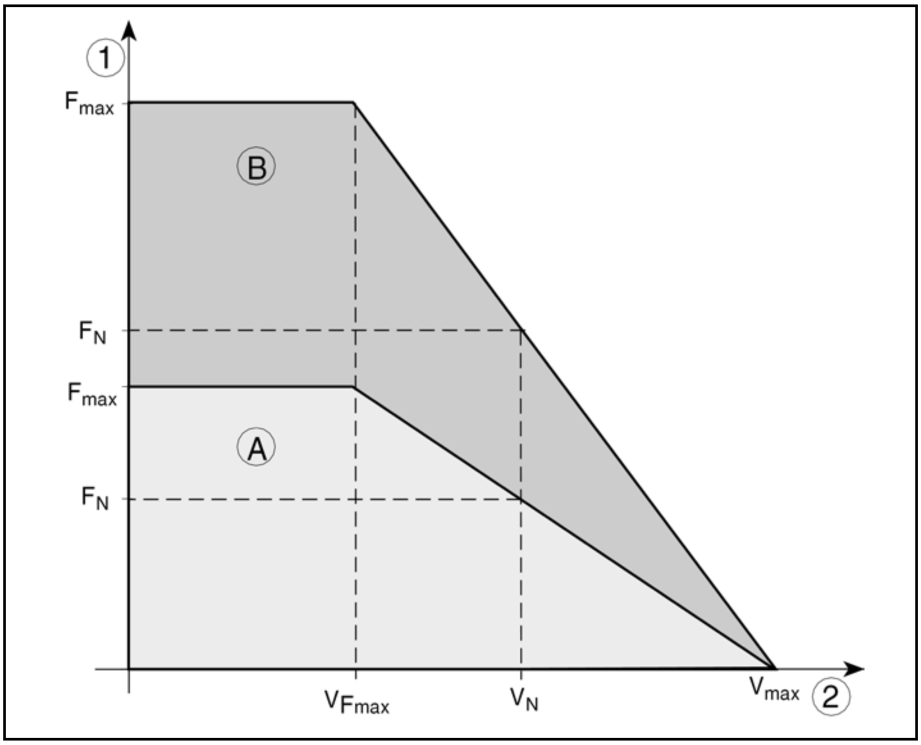
$$n_{max750V} = \frac{750V}{540V} \cdot n_{max} \qquad n_{nenn750V} = \frac{750V}{540V} \cdot n_{nenn}$$

Fig.4-3: Conversion example to DC bus voltage 750V_{DC}

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.



①	Feed force[N]
②	Velocity [m/min].
Ⓐ	Separate arrangement
Ⓑ	Parallel arrangement
Fig.4-4:	*Characteristic curve about force vs. velocity at for single and parallel connection of primary parts to one drive controller*

☞ For parallel connection of two primary parts at one drive controller, appropriate motor parameters for start-up are specified in this documentation (see chapter 13 "Commissioning, Operation and Maintenance" on page 241).

4.1.3 Characteristics

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

Continuous nominal force F_N Available continuous nominal force in operating mode S1 (contiuous operation) at standstill Unit Newton [N].

Maximum current I_{max} Maximum current (root-mean-square) of the motor at F_{max}. Unit Ampère [A].

Rated current I_N Phase current (effektive value) of the motor at a nominal velocity and load with continuous nominal force. Unit Ampère [A].

Maximum velocity v_{FMAX} with F_{max} 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 v_N Reachable nominal velocity at continuous 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 K_{EMF} bei 20 °C Electromagnetic Force. Induced motor voltage (effective value) dependend on the travel velocity regarding the velocity 1m/s. unit [Vs/m].

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

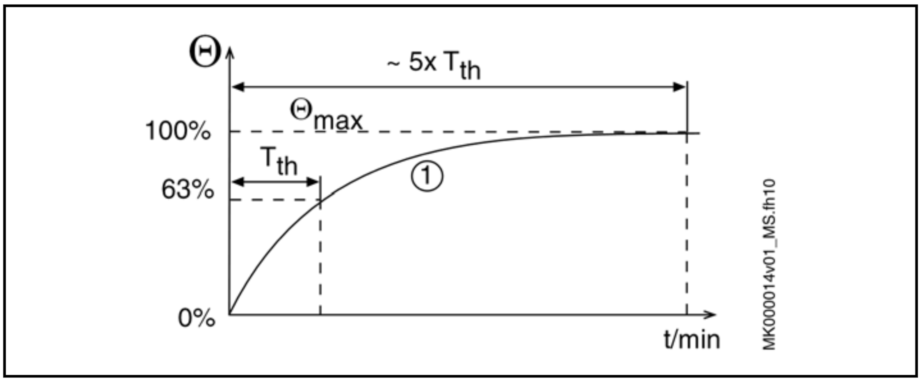
Winding inductivity L_{12} Measured winding inductivity between two strands. Unit [mH]. The defined measuring values are fluctuating due to boundary effects. The specifications are typical values, determined with a measuring voltage of 1 mA at a measuring frequence of 1 kHz.

Power wire cross-section A Necessary power wire cross-section rated for cable assemblies with current carrying capacity 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. When selecting the appropriate power cable, please observe the specifications in Chapter 8 on page 113 and the documentation of Rexroth about connection cables, MNR R911322949 (EN).

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]. Also refer toChapter 9.5 on page 139.

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
Θ_{max}	Max. winding temperature
T_{th}	Thermal time constant

Fig.4-5: Thermal time constant

Mass primary part with standard encapsulation m_{PS}
Mass primary part with standard encapsulation. Unit Kilogram [kg].

Mass primary part with thermal encapsulation m_{PT}
Mass primary part with thermal encapsulation. Unit Kilogram [kg].

Mass secondary part m_S
Mass secondary part. Unit Kilogram [kg].

Power loss to be dissipated P_V
Power loss in operation mode S1 (continuous operation) at nominal velocity v_N. Unit Watt [W].

Coolant inlet temperature T_{in}
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 on page 143 about coolant inlet temperature.

Allowed coolant temperature rise at ΔT_{max} bei P_V
Temperature difference between coolant inlet and outlet temperature during operation with liquid cooling (coolant water) and rated power loss P_{VN}. Unit Kelvin [K].

Necessary coolant flow Q_{min}
Necessary coolant flow to keep the specified rated feed force. Unit [l/min]. Please, observe the notes in Chapter 9.6 on page 143 about calculation of flow rate.

Pressure loss Δp at Q_{min}
Pressure loss within the internal coolant circuit of the motor Q_{min}. Please, observe the notes in Chapter 9.6 on page 143 about calculation of flow rate.

Constant to determine the pressure loss k_{dp}
Constant to determine the pressure loss within the motor internal coolant system with coolant water. Please, observe the notes in Chapter 9.6 on page 143 about calculation of flow rate.

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

E-file number
Test number of UL (=Underwriters Laboratories Inc.) certified products.

4.2 General Technical Data

For the sake of clarity, the following table contains data which is applicable to all motor frame sizes. In this context, however, the comments on the individual items in Chapter Application Notes must be observed.

Designation	Symbol	Unit	MLPxxx	MLSxxx
Ambient temperature in operation (see Fig. 9-70 on page 164)	T_{amb}	°C	0 ... +40	
Allowed transport temperature (see Fig. 11-6 on page 224)	T_T	°C	-20 ... +80	
Allowed storage temperature (see Fig. 11-11 on page 228)	T_L	°C	-20 ... +60	
Coolant inlet temperature (see Coolant inlet temperature on page 150	T_{in}	°C	+15 ... +40	
Allowed coolant temperature rise at P_V	ΔT_{max}	K	10	
Max. permitted secondary part temperature in operation	T_{Smax}	°C	/	70 °C
Temperature class according to DIN EN 60034-1	-	-	155 (F)	/
Warning temperature (winding)	T_{warn}	°C	145	/
Shutdown temperature (winding)	T_{shut}	°C	155	/
Degree of protection according to DIN EN 60034-5	-	-	IP65	
E-file number	-	-	E341734	
RoHS conformity according to EC guidelines 2002/95/EG	-	-	RoHS conform	
Latest amendment: 2012-05-03				

Fig.4-6: General Technical Data

4.3 Technical Data - Frame Size 040

4.3.1 Data MLP040

Parameter	Symbol	Unit	MLP040			
Frame Length			A	B		
Winding			0300	0150	0250	0300
Maximum force	F_{max}	N	800.0	1,150.0		
Continuous nominal force	F_N	N	250.0	370.0		
Maximum current	$I_{max(rms)}$	A	18.0	18.7	28.3	36.9
Rated current	I_N	A	3.8	3.9	5.6	6.3
Maximum velocity at F_{max}	v_{Fmax}	m/min	300	150	250	300
Nominal velocity	v_N	m/min	500	300	400	500
Force constant	K_{FN}	N/A	66.10	94.40	66.80	58.60
Voltage constant	K_{EMK}	Vs/m	38.1	54.4	38.5	33.8
Winding resistance at 20 °C	R_{12}	Ohm	8.6	12.8	6.3	5.0
Winding inductivity	L_{12}	mH	51.5	78.8	37.6	28.9
power wire cross-section	A	mm^2	1.0			
Pole width	t_p	mm	37.5			
Attractive force	F_{ATT}	N	1,200.0	1,700.0		
Thermal time constant	T_{th}	min	2.4			
Mass primary part with standard encapsulation	m_{PS}	kg	4.7	6.1		
Mass primary part with thermo encapsulation	m_{PT}	kg	6.1	8.1		
Data liquid cooling						
Power loss to be dissipated	P_V	W	400	550		
Necessary coolant flow at P_V	Q_{min}	l/min	0.6	0.8		
Pressure loss at Q_{min}	Δp	bar	0.1			
Constant for determining the pressure drop with standard encapsulation	$K_{\Delta p}$	--	6.1			
Constant for determining the pressure drop with thermo coupling	$K_{\Delta p}$	--	8.1			
Maximum allowed inlet pressure	p_{max}	bar	10.0			
						Latest amendment: 2012-09-12

Fig.4-7: MLP040 - Technical data

Technical Data IndraDyn L

4.3.2 Data MLS040

Designation	Symbol	Unit	MLS040S-3A-0150-NNNN	MLS040S-3A-0450-NNNN	MLS040S-3A-0600-NNNN
Secondary part mass	m_S	kg	0.8	2.4	3.2
Latest amendment: 2008-10-29					

Fig.4-8: MLS040 - Technical data

4.3.3 Motor Characteristic Curves Frame Size 040

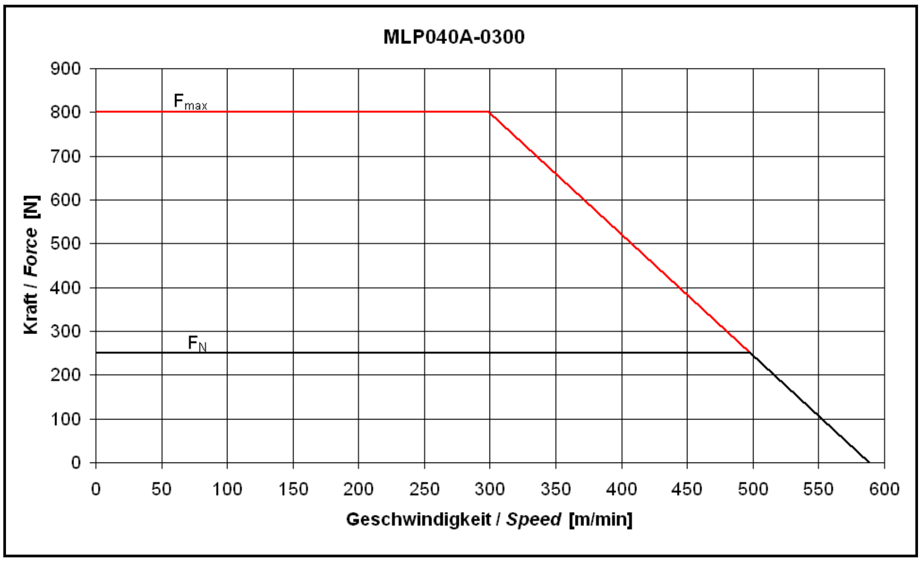


Fig.4-9: Motor characteristic curves MLP040A-0300

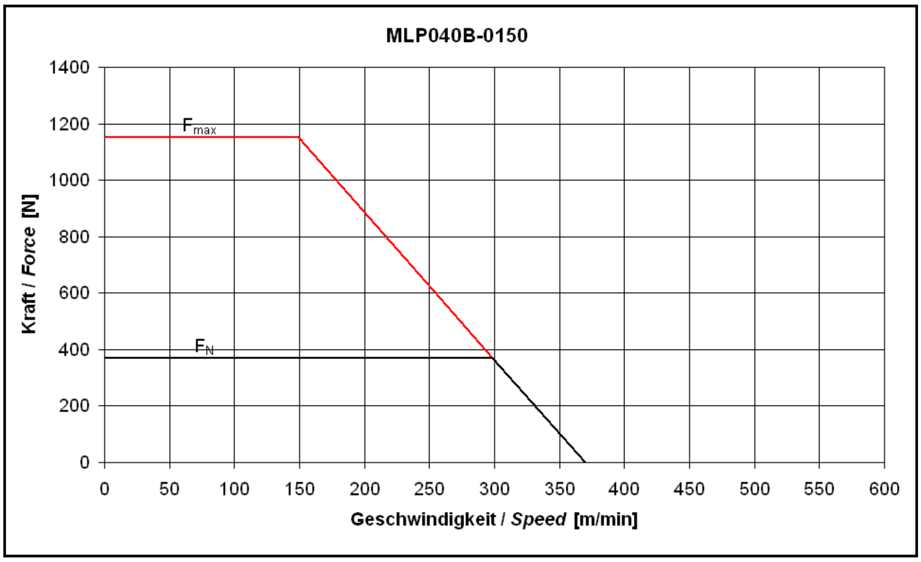


Fig.4-10: Motor characteristic curves MLP040B-0150

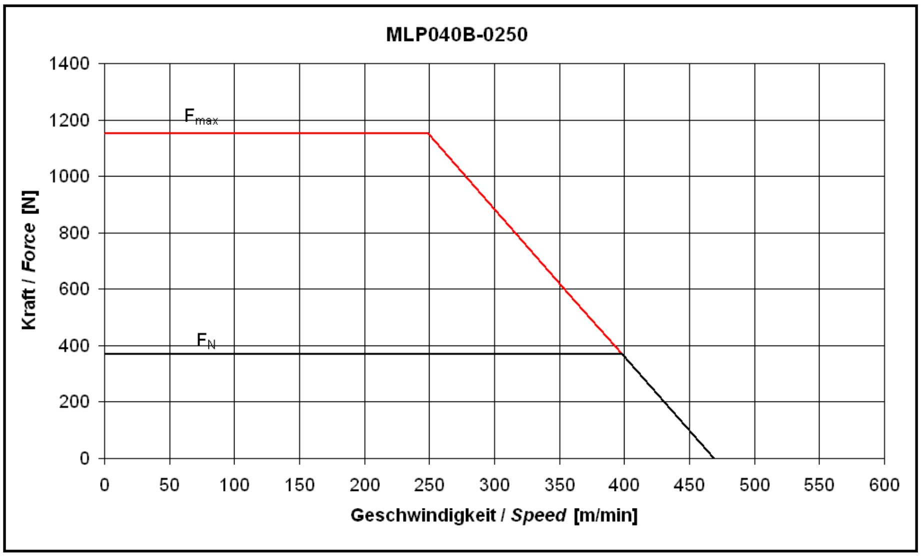


Fig.4-11: Motor characteristic curves MLP040B-0250

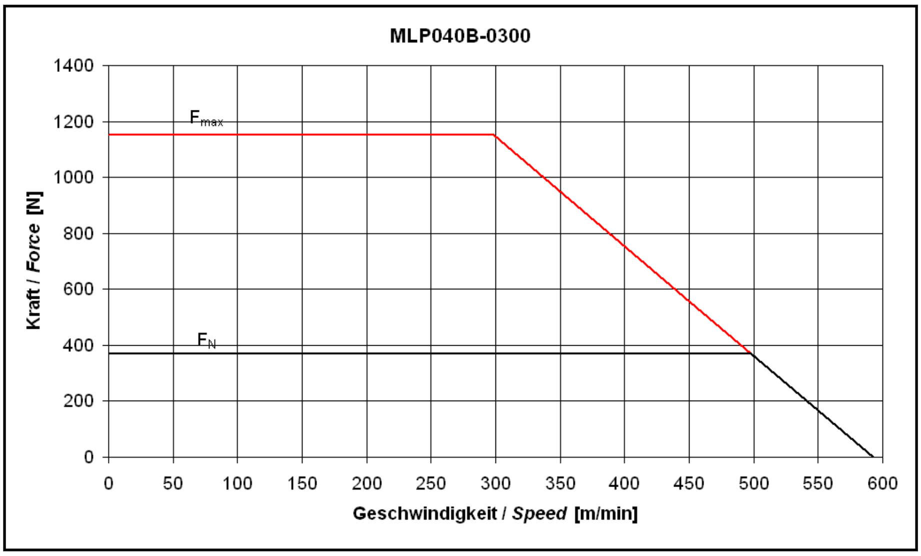


Fig.4-12: Motor characteristic curves MLP040B-0300

4.4 Technical Data - Frame Size 070

4.4.1 Data MLP070A

Parameter	Symbol	Unit	MLP070		
Frame Length			A		
Winding			0150	0220	0300
Maximum force	F_{max}	N	2,000.0		
Continuous nominal force	F_N	N	550.0		
Maximum current	$I_{max(rms)}$	A	29.6	40.5	42.0
Rated current	I_N	A	4.5	6.1	8.0
Maximum velocity at F_{max}	v_{Fmax}	m/min	150	220	300
Nominal velocity	v_N	m/min	200	360	450
Force constant	K_{FN}	N/A	121.70	90.70	68.70
Voltage constant	K_{EMK}	Vs/m	70.2	52.3	39.6
Winding resistance at 20 °C	R_{12}	Ohm	9.0	4.7	2.9
Winding inductivity	L_{12}	mH	55.7	26.9	17.1
power wire cross-section	A	mm²	1.0		
Pole width	t_p	mm	37.5		
Attractive force	F_{ATT}	N	2,900.0		
Thermal time constant	T_{th}	min	2.4		
Mass primary part with standard encapsulation	m_{PS}	kg	8.4		
Mass primary part with thermo encapsulation	m_{PT}	kg	10.9		
Data liquid cooling					
Power loss to be dissipated	P_V	W	780		
Necessary coolant flow at P_V	Q_{min}	l/min	1.1		
Pressure loss at Q_{min}	Δp	bar	0.2		
Constant for determining the pressure drop with standard encapsulation	$K_{\Delta p}$	--	8.4		
Constant for determining the pressure drop with thermo coupling	$K_{\Delta p}$	--	10.9		
Maximum allowed inlet pressure	p_{max}	bar	10.0		
Latest amendment: 2012-09-12					

Fig.4-13: MLP070A - Technical data

4.4.2 Motor Characteristic Curves MLP070A

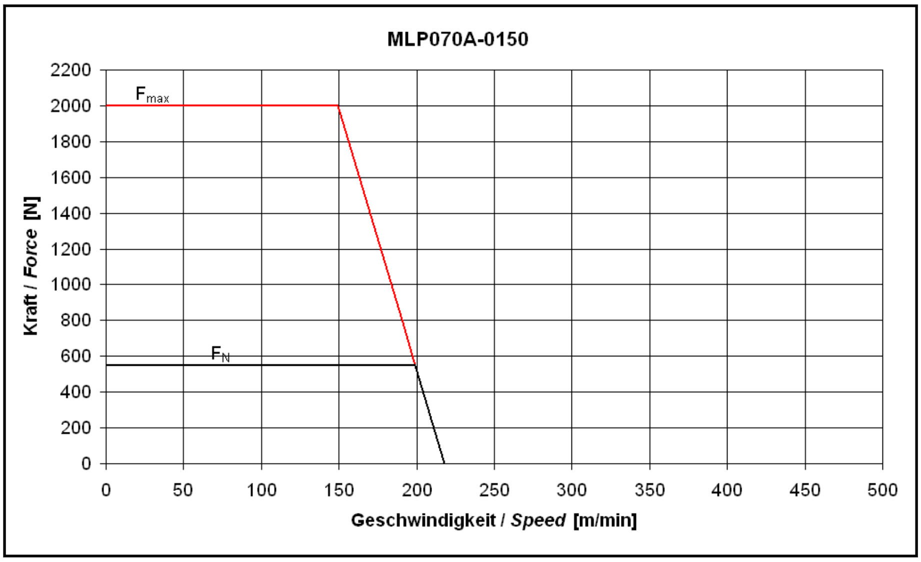


Fig.4-14: Motor characteristic curves MLP070A-0150

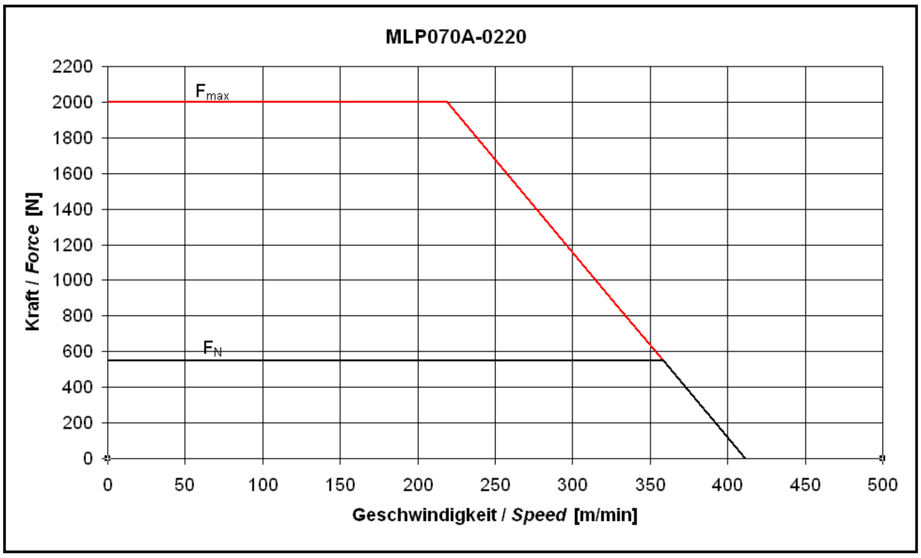


Fig.4-15: Motor characteristic curves MLP070A-0220

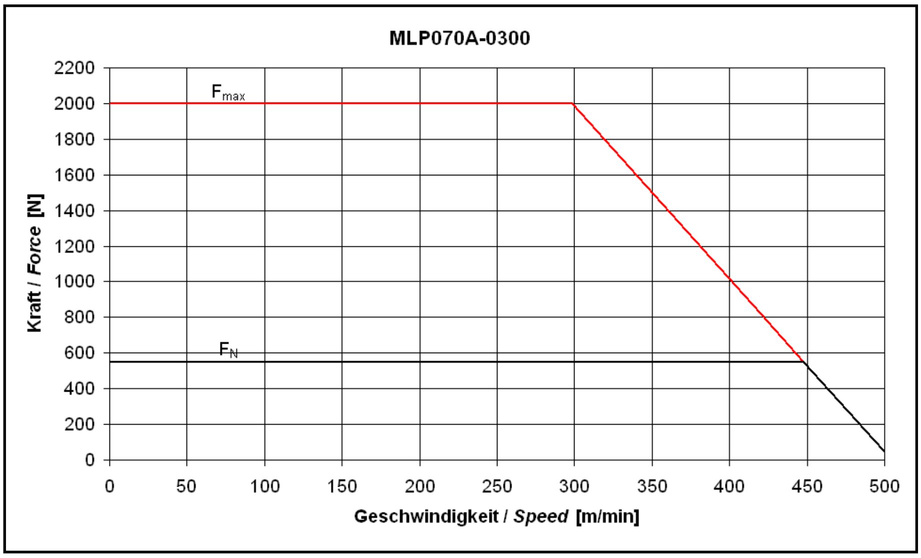


Fig.4-16: Motor characteristic curves MLP070A-0300

4.4.3 Data MLP070B

Parameter	Symbol	Unit	MLP070				
Frame Length			B				
Winding			0100	0120	0150	0250	0300
Maximum force	F_{max}	N	2,600.0				
Continuous nominal force	F_N	N	820.0				
Maximum current	$I_{max(rms)}$	A	23.6	42.8	56.8	57.1	67.7
Rated current	I_N	A	4.6	5.9	7.3	10.4	11.6
Maximum velocity at F_{max}	v_{Fmax}	m/min	100	120	150	250	300
Nominal velocity	v_N	m/min	200	220	260	400	450
Force constant	K_{FN}	N/A	176.70	138.80	111.90	79.10	70.70
Voltage constant	K_{EMK}	Vs/m	101.9	80.1	64.6	45.6	40.8
Winding resistance at 20 °C	R_{12}	Ohm	14.9	9.2	6.1	3.0	5.7
Winding inductivity	L_{12}	mH	89.0	55.3	35.0	17.0	36.2
power wire cross-section	A	mm^2	1.0				
Pole width	t_p	mm	37.5				
Attractive force	F_{ATT}	N	3,750.0				
Thermal time constant	T_{th}	min	2.4				
Mass primary part with standard encapsulation	m_{PS}	kg	10.4				
Mass primary part with thermo encapsulation	m_{PT}	kg	13.4				
Data liquid cooling							
Latest amendment: 2012-09-12							

Parameter	Symbol	Unit	MLP070				
Frame Length			B				
Winding			0100	0120	0150	0250	0300
Power loss to be dissipated	P_V	W	900				
Necessary coolant flow at P_V	Q_{min}	l/min	1.3				
Pressure loss at Q_{min}	Δp	bar	0.3				
Constant for determining the pressure drop with standard encapsulation	$K_{\Delta p}$	--	10.4				
Constant for determining the pressure drop with thermo coupling	$K_{\Delta p}$	--	13.4				
Maximum allowed inlet pressure	p_{max}	bar	10.0				
Latest amendment: 2012-09-12							

Fig.4-17: MLP070B - Technical data

4.4.4 Motor Characteristic Curves MLP070B

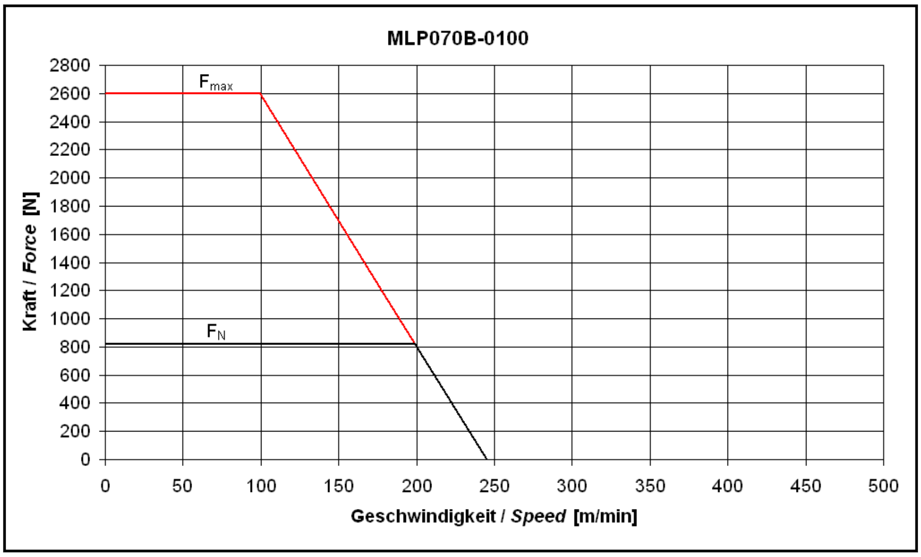


Fig.4-18: Motor characteristic curves MLP070B-0100

Technical Data IndraDyn L

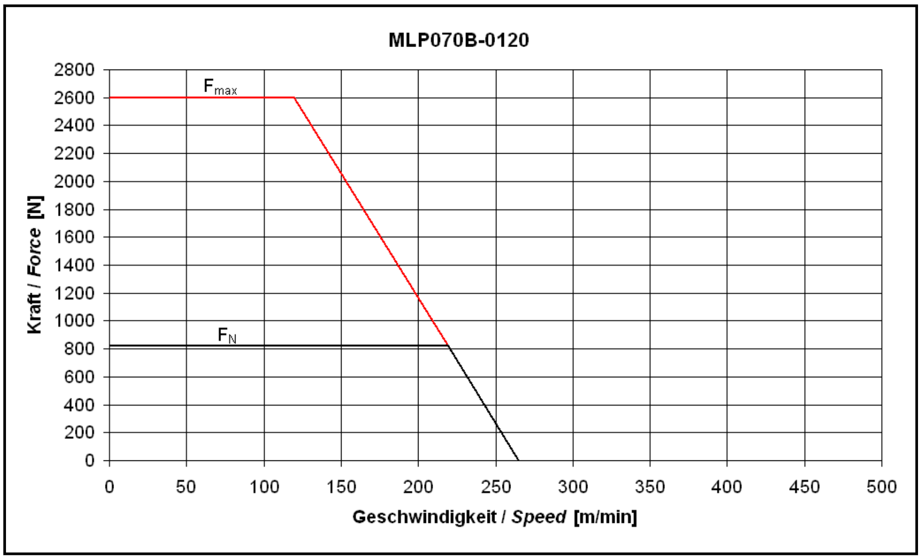


Fig.4-19: Motor characteristic curves MLP070B-0120

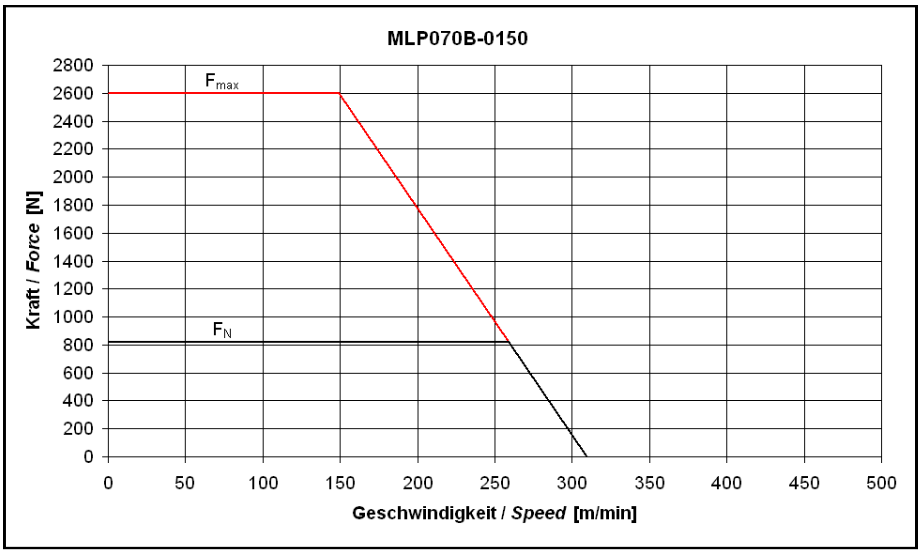


Fig.4-20: Motor characteristic curves MLP070B-0150

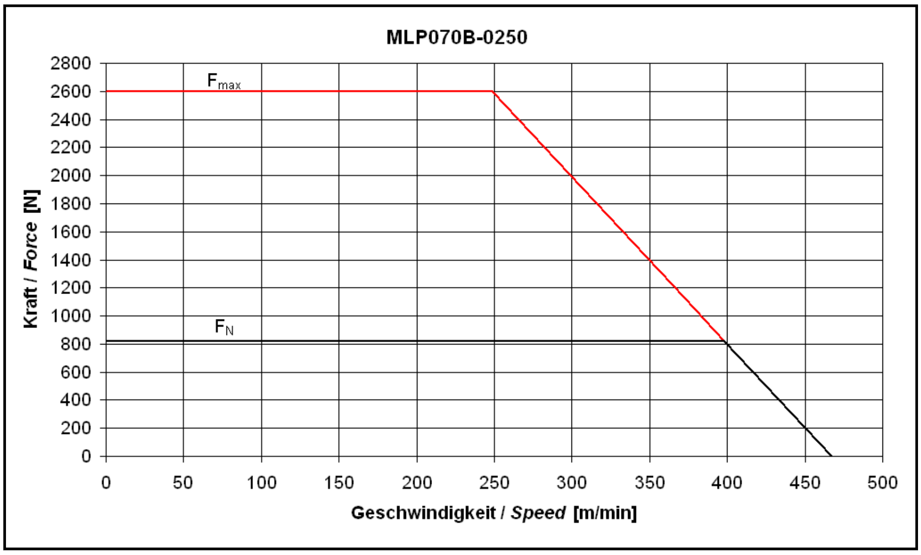


Fig.4-21: Motor characteristic curves MLP070B-0250

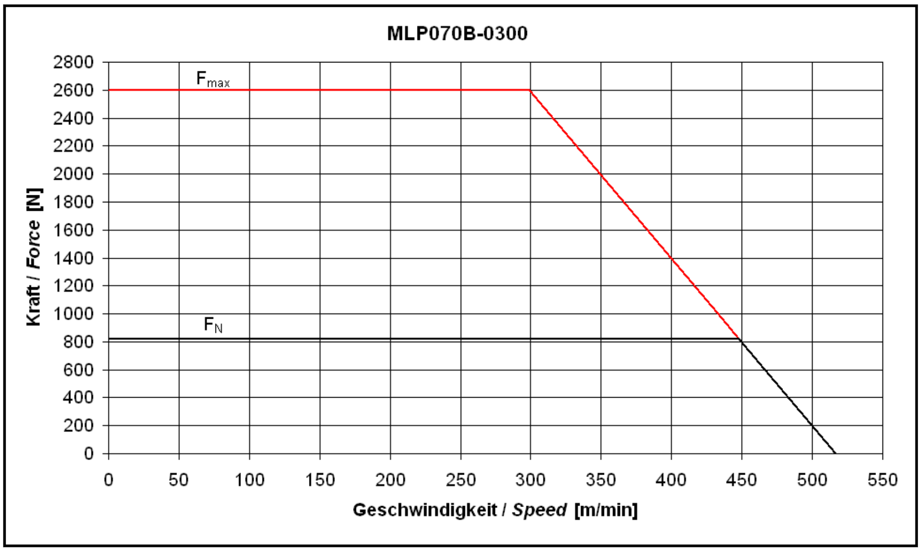


Fig.4-22: Motor characteristic curves MLP070B-0300

4.4.5 Data MLP070C

Parameter	Symbol	Unit	MLP070				
Frame Length			C				
Winding			0030	0120	0150	0240	0300
Maximum force	F_{max}	N	1,900.0	3,800.0			
Continuous nominal force	F_N	N	1,200.0				
Maximum current	$I_{max(rms)}$	A	6.5	56.9	65.9	107.9	106.7
Rated current	I_N	A	3.7	9.2	11.0	15.6	18.4
Maximum velocity at F_{max}	v_{Fmax}	m/min	30	120	150	240	300
Nominal velocity	v_N	m/min	70	180	250	350	450
Force constant	K_{FN}	N/A	326.10	130.40	109.10	77.10	65.20
Voltage constant	K_{EMK}	Vs/m	188.7	75.2	62.9	44.5	37.6
Winding resistance at 20 °C	R_{12}	Ohm	4.0	5.7	4.05	2.0	1.46
Winding inductivity	L_{12}	mH	22.6	36.2	24.5	11.6	10.2
power wire cross-section	A	mm^2	1.0				2.5
Pole width	t_p	mm	37.5				
Attractive force	F_{ATT}	N	5,500.0				
Thermal time constant	T_{th}	min	2.4				
Mass primary part with standard encapsulation	m_{PS}	kg	14.3				
Mass primary part with thermo encapsulation	m_{PT}	kg	18.4				
Data liquid cooling							
Power loss to be dissipated	P_V	W	1,100				
Necessary coolant flow at P_V	Q_{min}	l/min	1.6				
Pressure loss at Q_{min}	Δp	bar	0.4				
Constant for determining the pressure drop with standard encapsulation	$K_{\Delta p}$	--	14.3				
Constant for determining the pressure drop with thermo coupling	$K_{\Delta p}$	--	18.4				
Maximum allowed inlet pressure	p_{max}	bar	10.0				
Latest amendment: 2012-09-12							

Fig.4-23: MLP070C - Technical data

4.4.6 Motor Characteristic Curves MLP070C

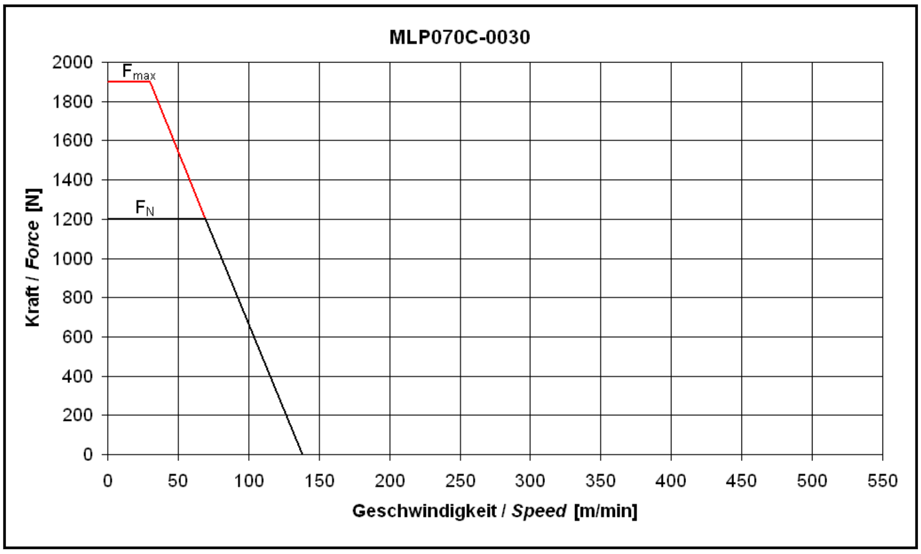


Fig.4-24: Motor characteristic curves MLP070C-0030

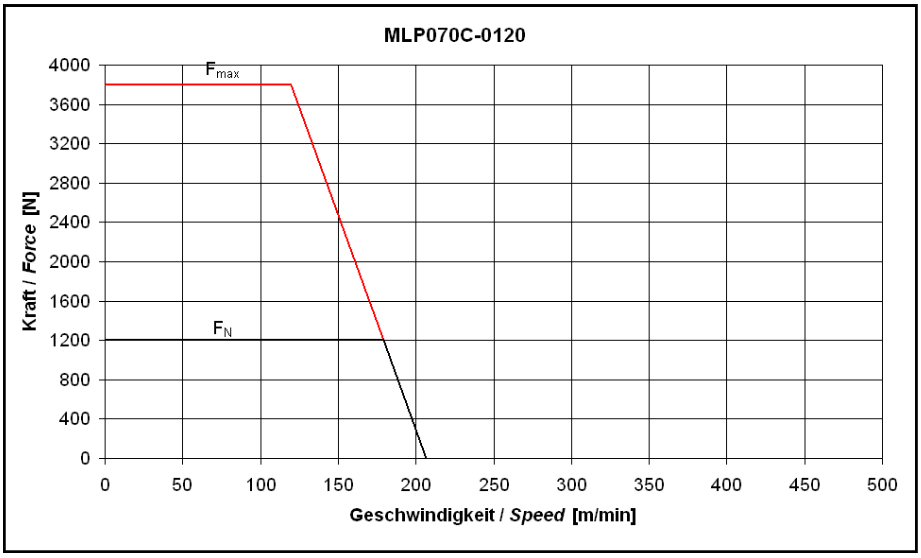


Fig.4-25: Motor characteristic curves MLP070C-0120

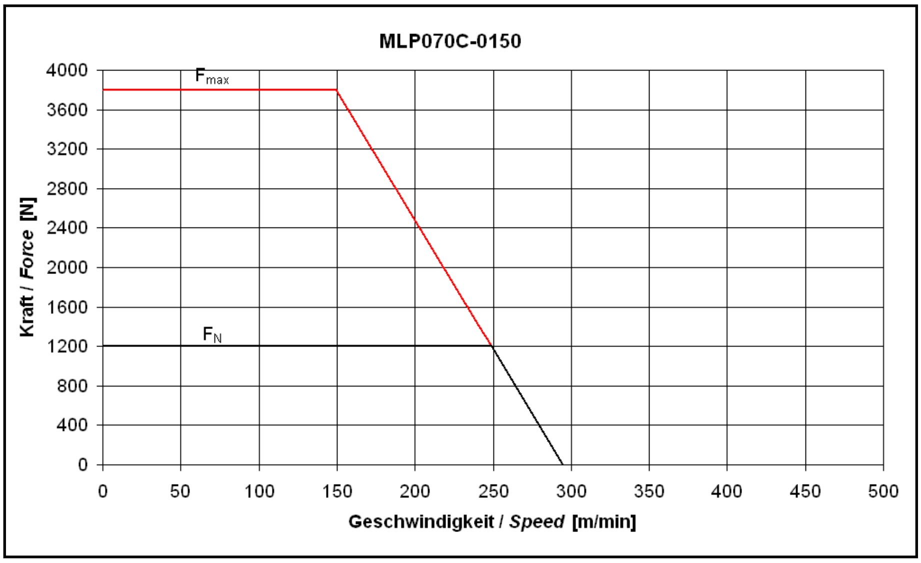


Fig.4-26: Motor characteristic curves MLP070C-0150

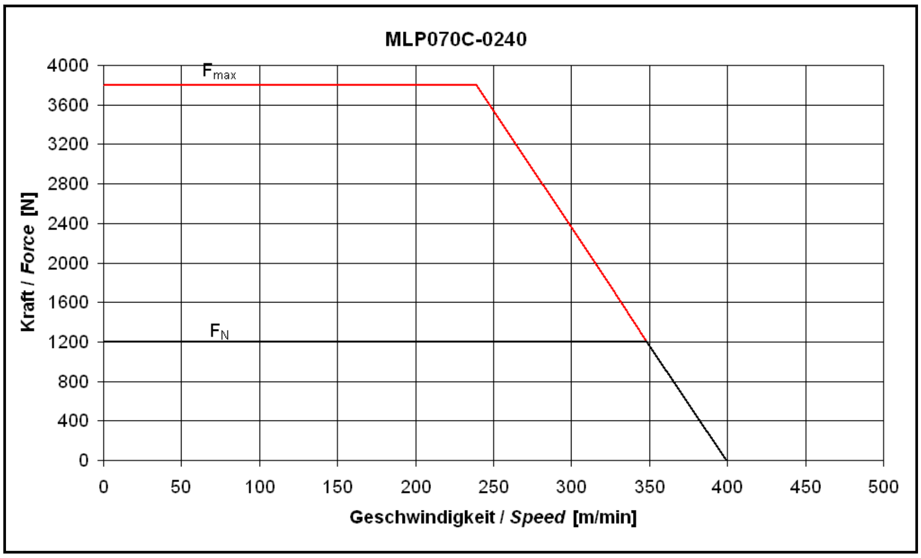


Fig.4-27: Motor characteristic curves MLP070C-0240

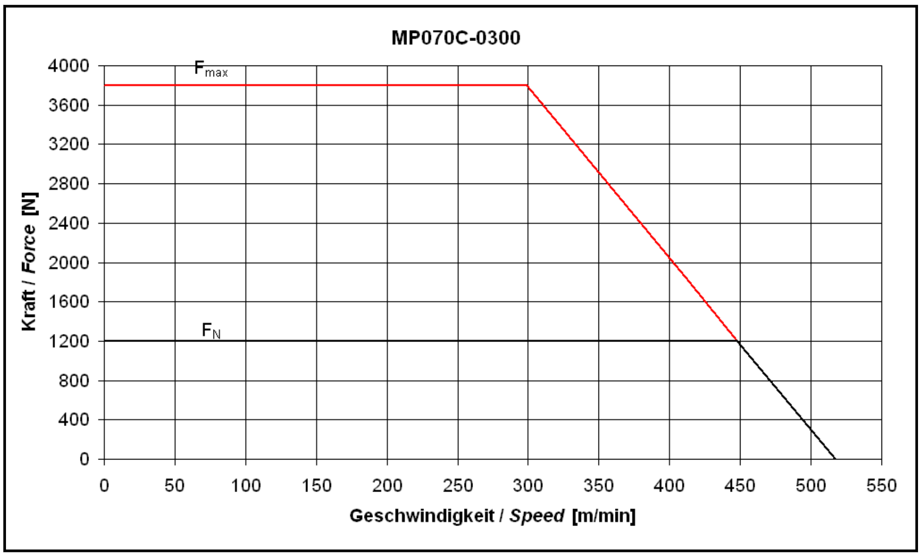


Fig.4-28: Motor characteristic curves MLP070C-0300

4.4.7 Data MLS070

Designation	Symbol	Unit	MLS070S-3A-0150-NNNN	MLS070S-3A-0450-NNNN	MLS070S-3A-0600-NNNN
Secondary part mass	m_S	kg	1.4	4.2	5.6
Latest amendment: 2008-10-29					

Fig.4-29: MLS070 - Technical data

4.5 Technical Data - Frame Size 100

4.5.1 Data MLP100A

Parameter	Symbol	Unit	MLP100			
Frame Length			A			
Winding			0090	0120	0150	0190
Maximum force	F_{max}	N	3,750.0			
Continuous nominal force	F_N	N	1,180.0			
Maximum current	$I_{max(rms)}$	A	34.2	40.5	50.8	69.2
Rated current	I_N	A	5.9	7.4	9.2	11.9
Maximum velocity at F_{max}	v_{Fmax}	m/min	90	120	150	190
Nominal velocity	v_N	m/min	150	190	220	290
Force constant	K_{FN}	N/A	198.90	160.40	127.80	99.50
Voltage constant	K_{EMK}	Vs/m	114.8	92.5	73.8	57.4
Winding resistance at 20 °C	R_{12}	Ohm	12.0	7.9	4.9	3.0
Winding inductivity	L_{12}	mH	66.9	43.8	27.3	16.5
Power wire cross-section	A	mm^2	1.0			
Pole width	t_p	mm	37.5			
Attractive force	F_{ATT}	N	5,400.0			
Thermal time constant	T_{th}	min	2.4			
Mass primary part with standard encapsulation	m_{PS}	kg	13.5			
Mass primary part with thermo encapsulation	m_{PT}	kg	17.0			
Data liquid cooling						
Power loss to be dissipated	P_V	W	1,500			
Necessary coolant flow at P_V	Q_{min}	l/min	2.0			
Pressure loss at Q_{min}	Δp	bar	0.3			
Constant for determining the pressure drop with standard encapsulation	$K_{\Delta p}$	--	13.5			
Constant for determining the pressure drop with thermo coupling	$K_{\Delta p}$	--	17.0			
Maximum allowed inlet pressure	p_{max}	bar	10.0			
Latest amendment: 2012-09-12						

Fig.4-30: MLP100A - Technical data

4.5.2 Motor Characteristic Curves MLP100A

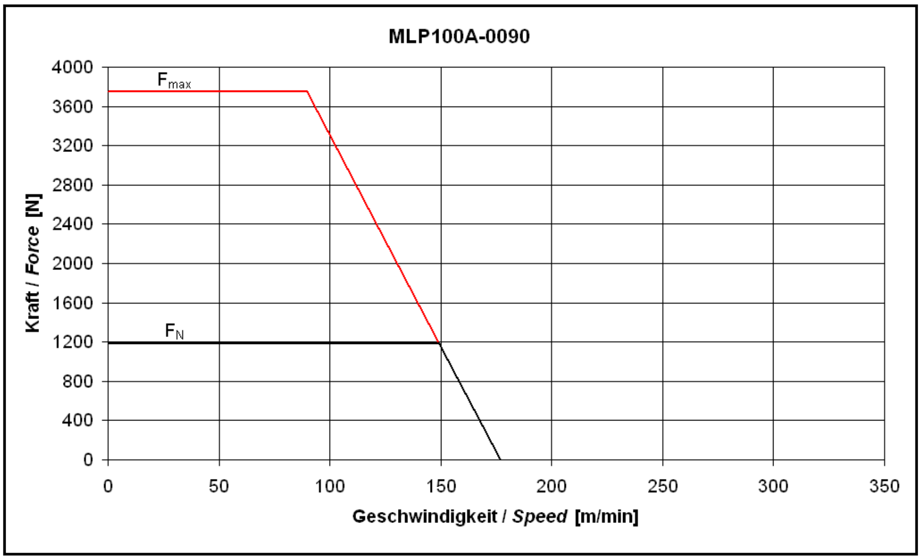


Fig.4-31: Motor characteristic curves MLP100A-0090

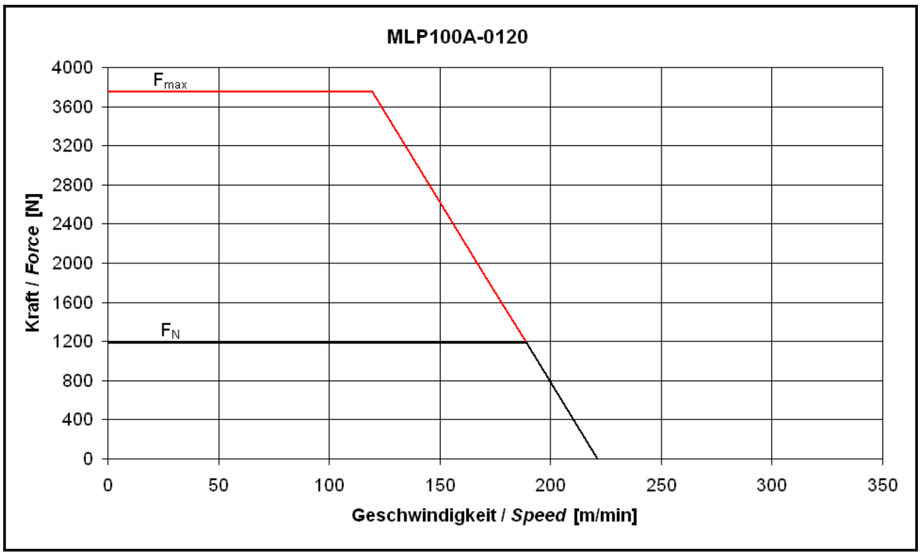


Fig.4-32: Motor characteristic curves MLP100A-0120

Technical Data IndraDyn L

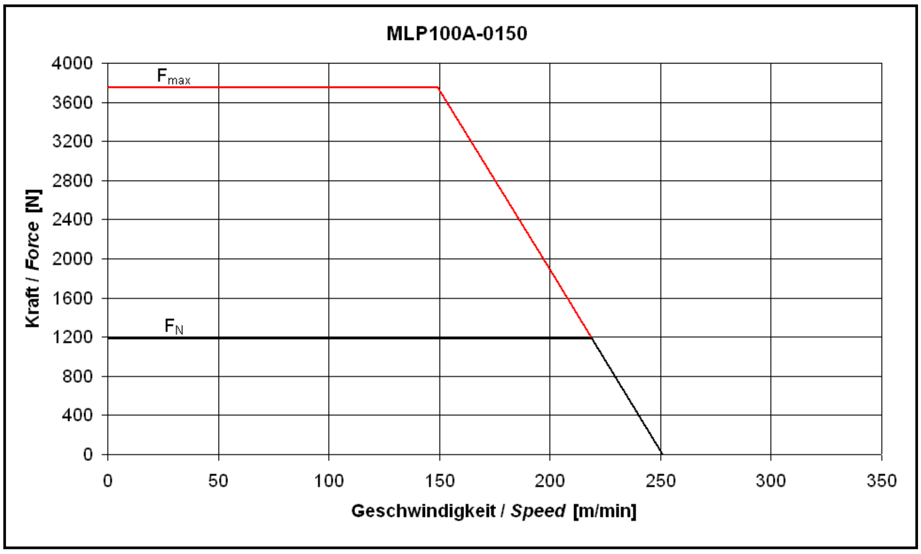


Fig.4-33: Motor characteristic curves MLP100A-0150

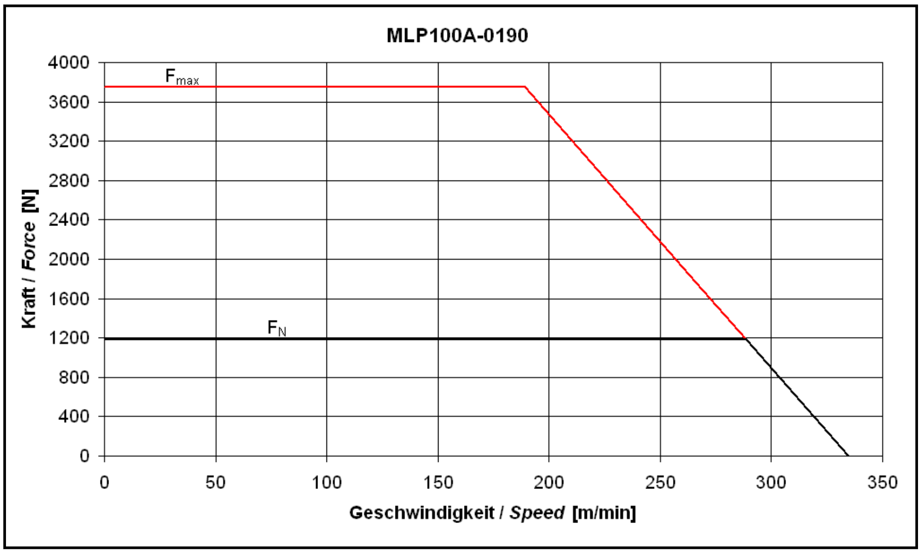


Fig.4-34: Motor characteristic curves MLP100A-0190

4.5.3 Data MLP100B, MLP100C

Parameter	Symbol	Unit	MLP100					
Frame Length			B			C		
Winding			0030	0120	0250	0090	0120	0190
Maximum force	F_{max}	N	3,000.0	5,600.0		7,150.0		
Continuous nominal force	F_N	N	1,785.0			2,310.0		
Maximum current	$I_{max(rms)}$	A	9.7	71.2	142.6	83.6	84.9	147.1
Rated current	I_N	A	5.1	12.2	24.1	12.1	15.0	24.2
Maximum velocity at F_{max}	v_{Fmax}	m/min	30	120	250	90	120	190
Nominal velocity	v_N	m/min	70	190	350	170	190	290
Force constant	K_{FN}	N/A	352.40	146.30	74.10	191.30	154.20	95.70
Voltage constant	K_{EMK}	Vs/m	203.4	84.4	42.7	110.4	89.0	55.2
Winding resistance at 20 °C	R_{12}	Ohm	26.4	4.5	1.2	6.0	4.0	1.5
Winding inductivity	L_{12}	mH	137.0	25.6	6.5	35.3	22.6	8.5
Power wire cross-section	A	mm^2	1.0		2.5	1.0	1.5	4.0
Pole width	t_p	mm	37.5					
Attractive force	F_{ATT}	N	8,000.0			10,400.0		
Thermal time constant	T_{th}	min	2.4					
Mass primary part with standard encapsulation	m_{PS}	kg	18.7			24.0		
Mass primary part with thermo encapsulation	m_{PT}	kg	23.3			29.7		
Data liquid cooling								
Power loss to be dissipated	P_V	W	1,300			1,600		
Necessary coolant flow at P_V	Q_{min}	l/min	1.9			2.3		
Pressure loss at Q_{min}	Δp	bar	0.5			0.8		
Constant for determining the pressure drop with standard encapsulation	$K_{\Delta p}$	--	18.7			24.0		
Constant for determining the pressure drop with thermo coupling	$K_{\Delta p}$	--	23.3			29.7		
Maximum allowed inlet pressure	p_{max}	bar	10.0					
Latest amendment: 2012-09-12								

Fig.4-35: MLP100B, MLP100C - Technical data

Technical Data IndraDyn L

4.5.4 Motor Characteristic Curves MLP100B

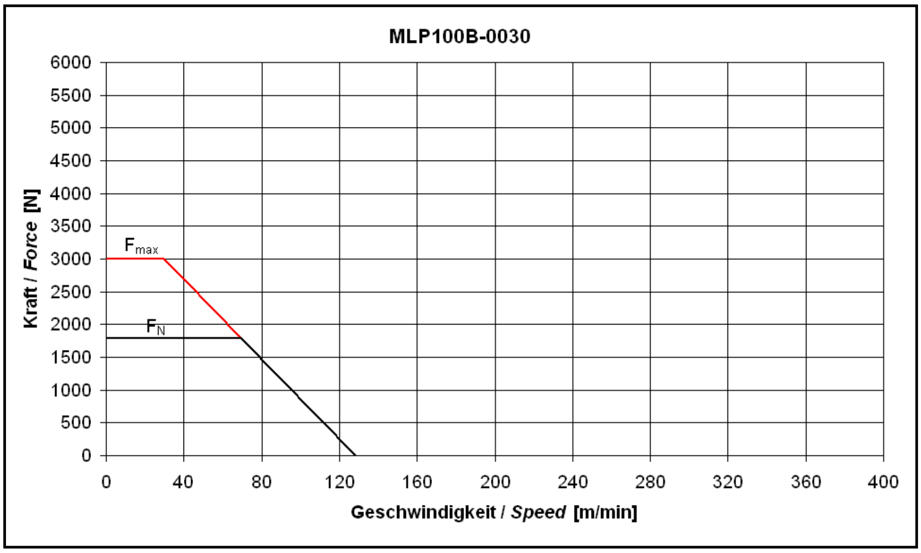


Fig.4-36: Motor characteristic curves MLP100B-0030

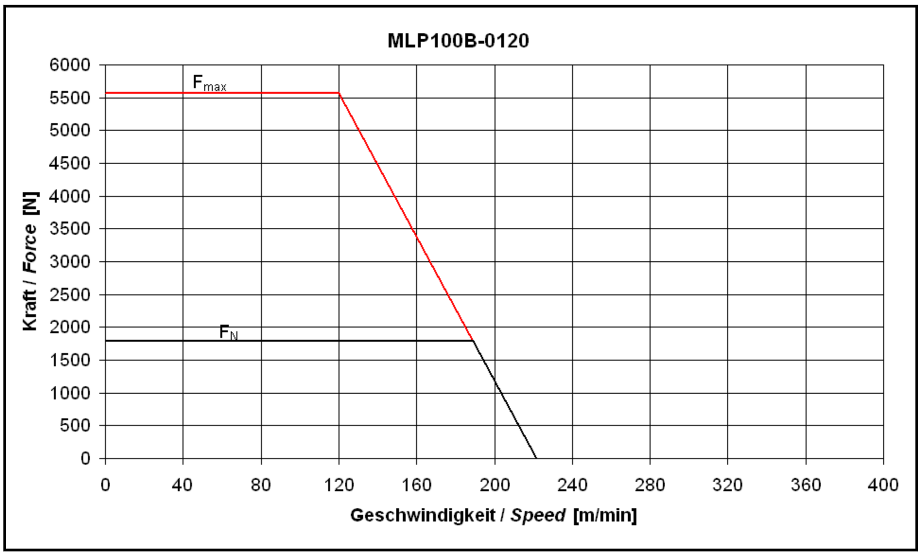


Fig.4-37: Motor characteristic curves MLP100B-0120

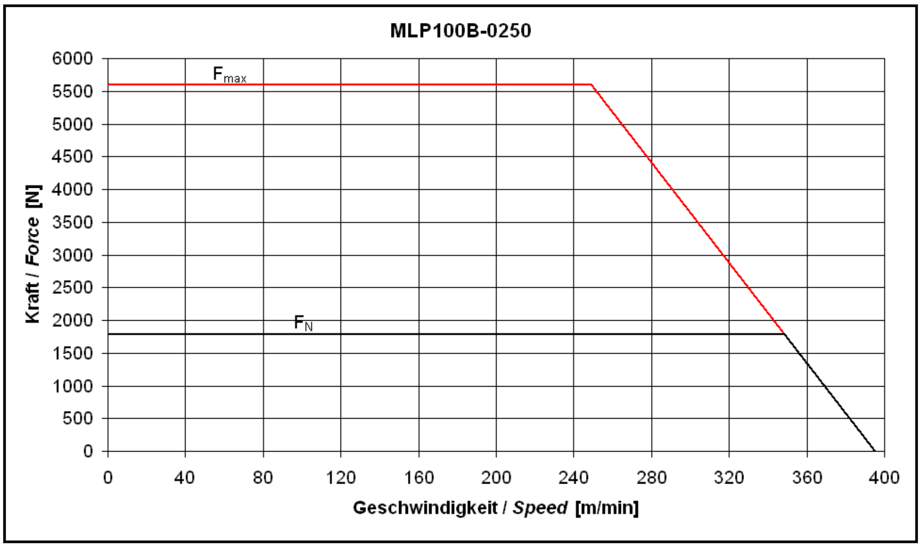


Fig.4-38: Motor characteristic curves MLP100B-0250

4.5.5 Motor Characteristic Curves MLP100C

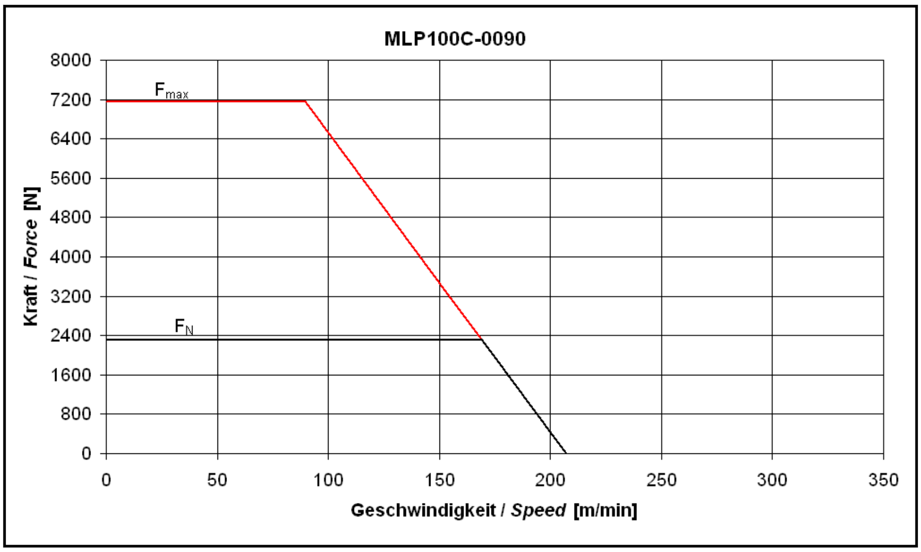


Fig.4-39: Motor characteristic curves MLP100C-0090

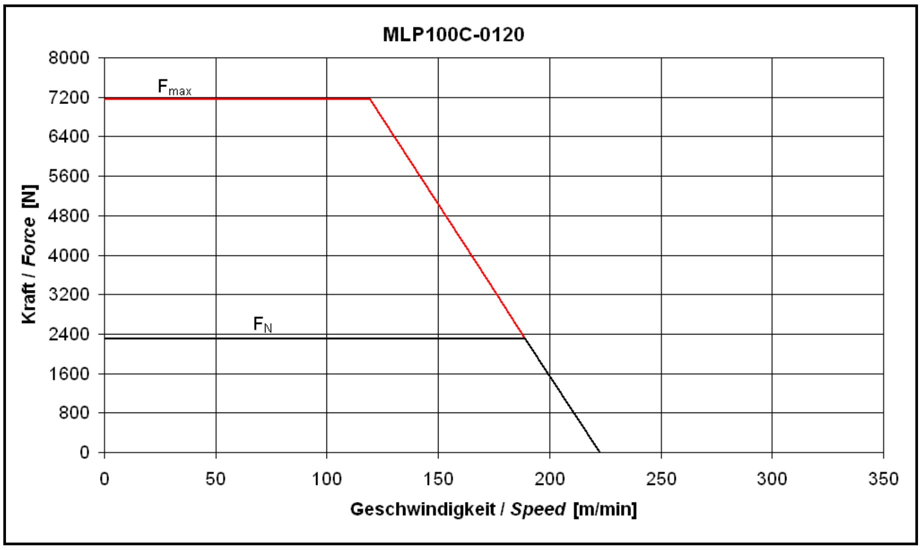


Fig.4-40: Motor characteristic curves MLP100C-0120

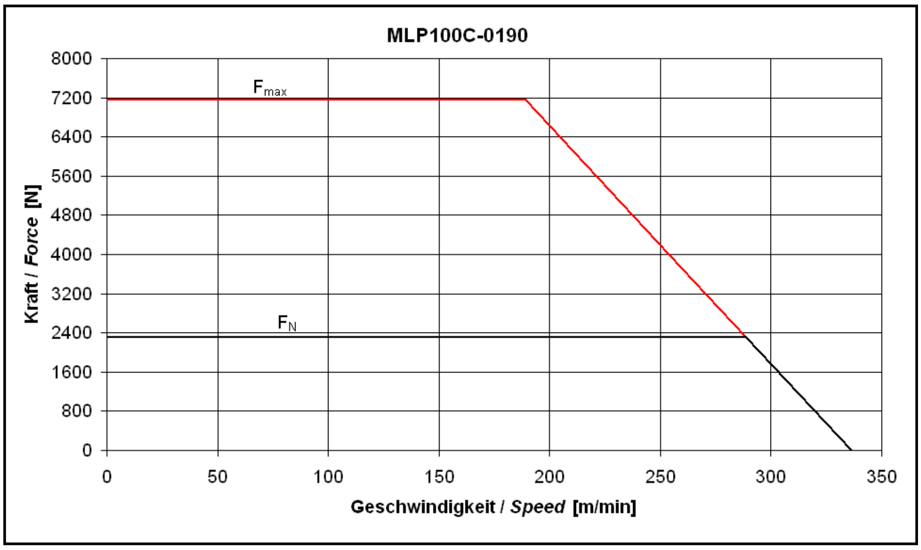


Fig.4-41: Motor characteristic curves MLP100C-0190

4.5.6 Data MLS100

Designation	Symbol	Unit	MLS100S-3A-0150-NNNN	MLS100S-3A-0450-NNNN	MLS100S-3A-0600-NNNN
Secondary part mass	m_S	kg	2.0	6.0	8.0
Latest amendment: 2008-10-29					

Fig.4-42: MLS100 - Technical data

4.6 Technical Data - Frame Size 140

4.6.1 Data MLP140A, MLP140B

Parameter	Symbol	Unit	MLP140			
Frame Length			A		B	
Winding			0030	0120	0090	0120
Maximum force	F_{max}	N	3,000.0	5,200.0	7,650.0	
Continuous nominal force	F_N	N	1,680.0		2,415.0	
Maximum current	$I_{max(rms)}$	A	10.5	70.8	79.3	103.8
Rated current	I_N	A	5.0	12.1	14.0	17.8
Maximum velocity at F_{max}	v_{Fmax}	m/min	30	120	90	120
Nominal velocity	v_N	m/min	75	190	160	190
Force constant	K_{FN}	N/A	337.60	138.50	172.80	135.80
Voltage constant	K_{EMK}	Vs/m	194.9	79.9	99.7	78.3
Winding resistance at 20 °C	R_{12}	Ohm	3.6		4.3	2.6
Winding inductivity	L_{12}	mH	20.2		23.1	14.2
Power wire cross-section	A	mm^2	1.0		1.5	2.5
Pole width	t_p	mm	37.5			
Attractive force	F_{ATT}	N	7,500.0		11,000.0	
Thermal time constant	T_{th}	min	2.4			
Mass primary part with standard encapsulation	m_{PS}	kg	17.0		24.5	
Mass primary part with thermo encapsulation	m_{PT}	kg	21.2		30.1	
Data liquid cooling						
Power loss to be dissipated	P_V	W	1,300		2,512	
Necessary coolant flow at P_V	Q_{min}	l/min	1.9		3.6	
Pressure loss at Q_{min}	Δp	bar	0.6		0.9	
Constant for determining the pressure drop with standard encapsulation	$K_{\Delta p}$	--	24.5			
Constant for determining the pressure drop with thermo coupling	$K_{\Delta p}$	--	30.1			
Maximum allowed inlet pressure	p_{max}	bar	10.0			
Latest amendment: 2012-09-12						

Fig.4-43: MLP140A, MLP140B - Technical data

4.6.2 Motor Characteristic Curves MLP140A

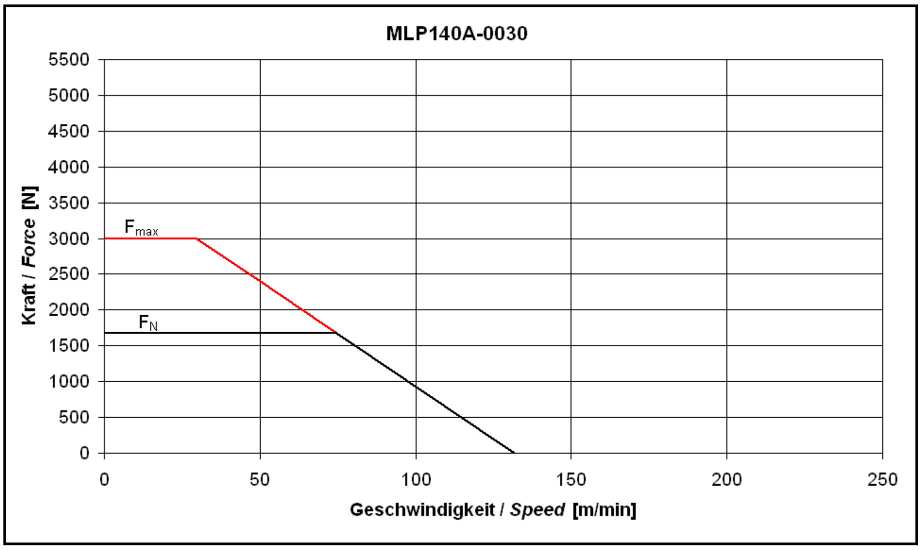


Fig.4-44: Motor characteristic curves MLP140A-0030

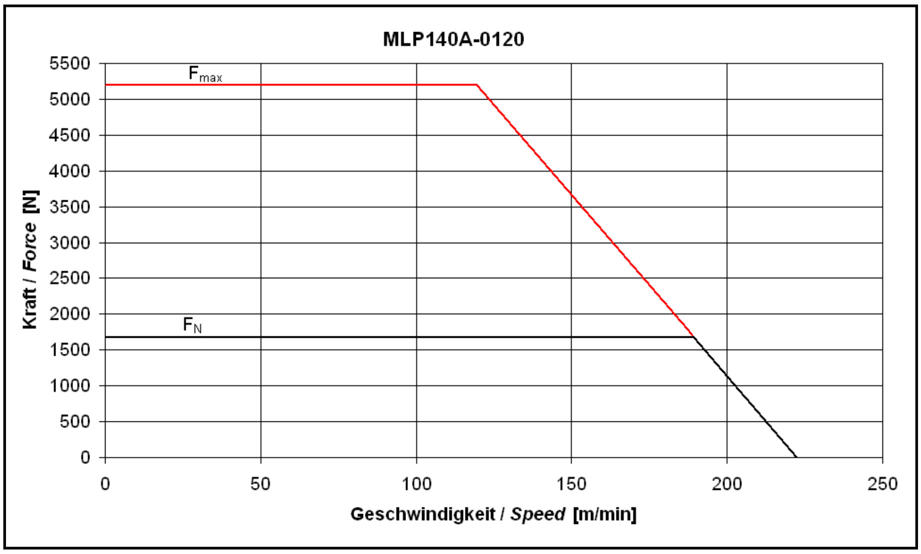


Fig.4-45: Motor characteristic curves MLP140A-0120

4.6.3 Motor Characteristic Curves MLP140B

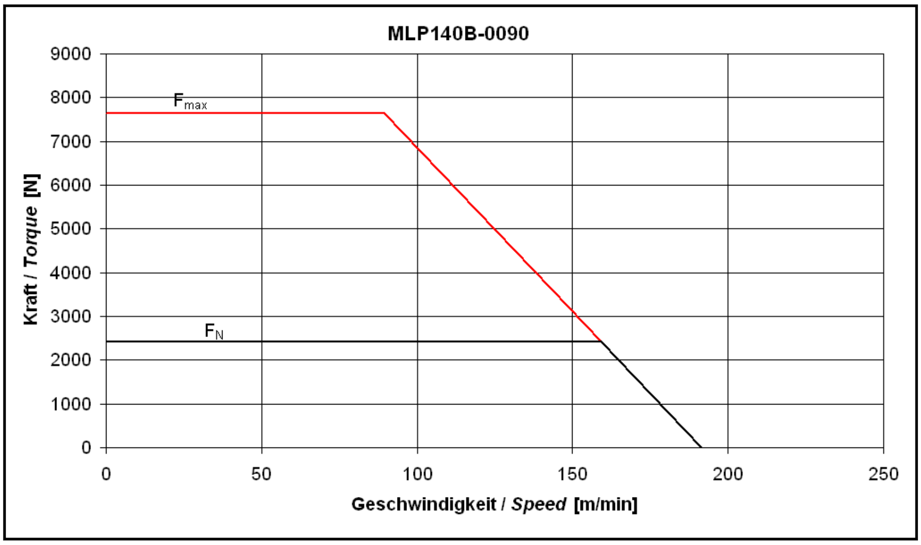


Fig.4-46: Motor characteristic curves MLP140B-0090

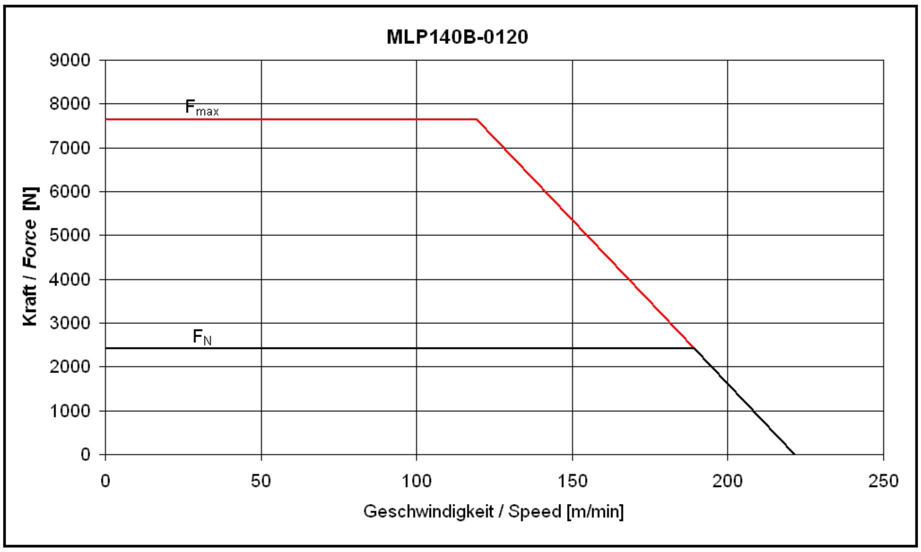


Fig.4-47: Motor characteristic curves MLP140B-0120

4.6.4 Data MLP140C

Parameter	Symbol	Unit	MLP140			
Frame Length			C			
Winding			0050	0120	0170	0350
Maximum force	F_{max}	N	10,000.0			
Continuous nominal force	F_N	N	3,150.0			
Maximum current	$I_{max(rms)}$	A	78.6	122.9	137.8	231.1
Rated current	I_N	A	14.6	20.7	28.5	47.1
Maximum velocity at F_{max}	v_{Fmax}	m/min	50	120	170	350
Nominal velocity	v_N	m/min	110	190	250	400
Force constant	K_{FN}	N/A	215.90	152.60	110.40	66.90
Voltage constant	K_{EMK}	Vs/m	124.6	88.1	63.7	38.6
Winding resistance at 20 °C	R_{12}	Ohm	5.2	2.55	1.34	0.49
Winding inductivity	L_{12}	mH	28.5	13.0	6.8	2.6
Power wire cross-section	A	mm^2	1.0	2.5	4.0	10.0
Pole width	t_p	mm	37.5			
Attractive force	F_{ATT}	N	14400.0			
Thermal time constant	T_{th}	min	2.4			
Mass primary part with standard encapsulation	m_{PS}	kg	32.0			
Mass primary part with thermo encapsulation	m_{PT}	kg	38.9			
Data liquid cooling						
Power loss to be dissipated	P_V	W	2000			
Necessary coolant flow at P_V	Q_{min}	l/min	2.9			
Pressure loss at Q_{min}	Δp	bar	1.2			
Constant for determining the pressure drop with standard encapsulation	$K_{\Delta p}$	--	32.0			
Constant for determining the pressure drop with thermo coupling	$K_{\Delta p}$	--	38.9			
Maximum allowed inlet pressure	p_{max}	bar	10.0			
Latest amendment: 2012-09-12						

Fig.4-48: MLP140C - Technical data

4.6.5 Motor Characteristic Curves MLP140C

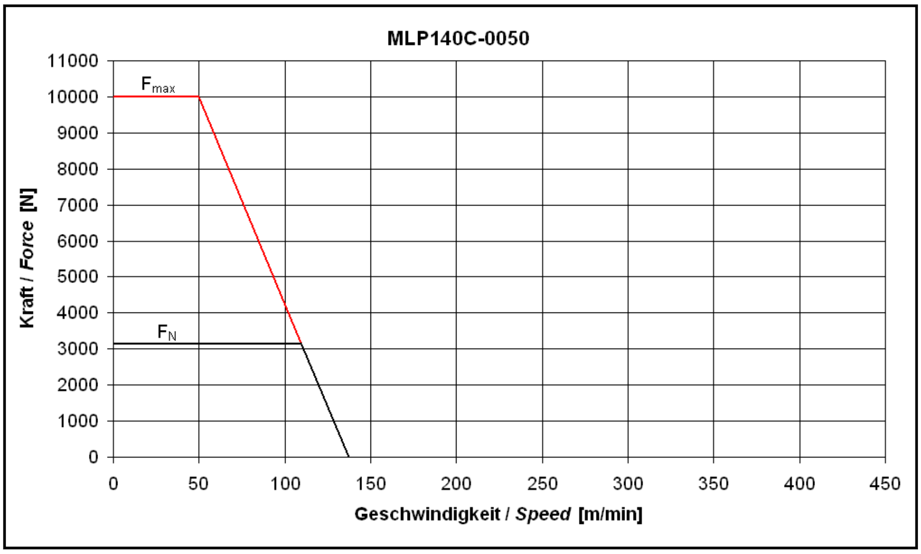


Fig.4-49: Motor characteristic curves MLP140C-0050

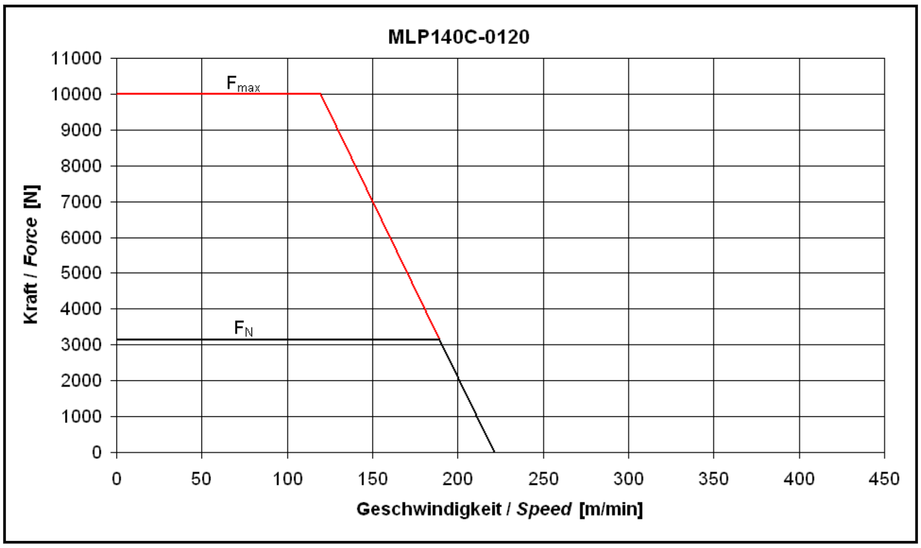


Fig.4-50: Motor characteristic curves MLP140C-0120

Technical Data IndraDyn L

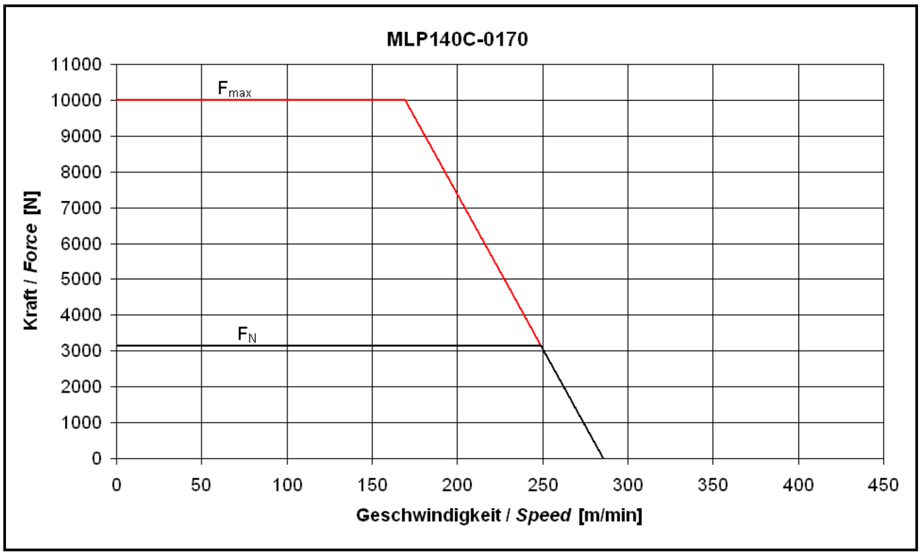


Fig.4-51: Motor characteristic curves MLP140C-0170

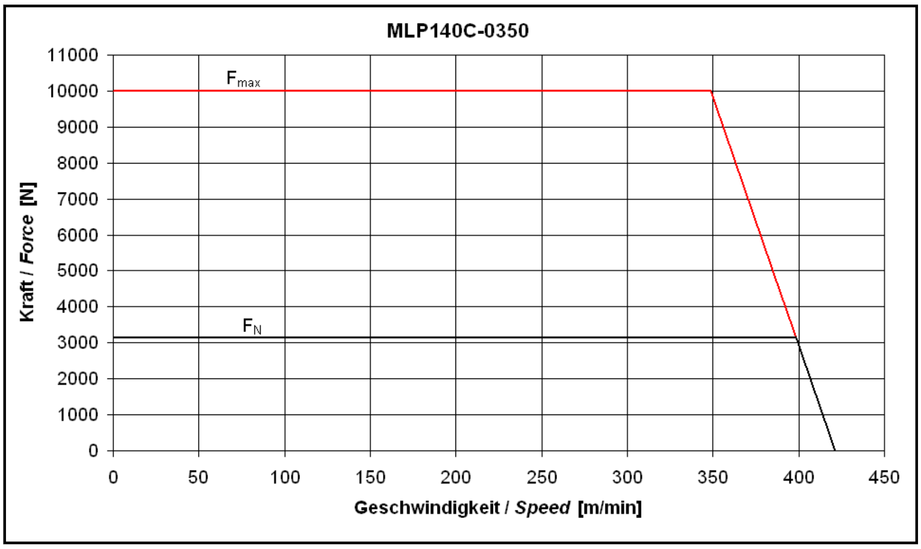


Fig.4-52: Motor characteristic curves MLP140C-0350

4.6.6 Data MLS140

Designation	Symbol	Unit	MLS140_-__-0150	MLS140_-__-0450	MLS140_-__-0600
Secondary part mass	m_S	kg	2.8	8.5	11.3
					Latest amendment: 2008-10-29

Fig.4-53: MLS140 - Technical data

4.7 Technical Data - Frame Size 200

4.7.1 Frame Size MLP200A, MLP200B

Parameter	Symbol	Unit	MLP200			
Frame Length			A		B	
Winding			0090	0120	0040	0120
Maximum force	F_{max}	N	7,450.0		10,900.0	
Continuous nominal force	F_N	N	2,415.0		3,465.0	
Maximum current	$I_{max(rms)}$	A	69.6	81.3	74.2	128.6
Rated current	I_N	A	12.9	14.8	13.8	21.8
Maximum velocity at F_{max}	v_{Fmax}	m/min	90	120	40	120
Nominal velocity	v_N	m/min	170	190	100	190
Force constant	K_{FN}	N/A	186.70	163.50	251.40	159.30
Voltage constant	K_{EMK}	Vs/m	107.8	94.3	145.1	91.9
Winding resistance at 20 °C	R_{12}	Ohm	4.5	2.3	5.7	2.34
Winding inductivity	L_{12}	mH	22.7	14.0	29.7	12.1
Power wire cross-section	A	mm^2	1.0	2.5	1.0	2.5
Pole width	t_p	mm	37.5			
Attractive force	F_{ATT}	N	10,700.0		15,600.0	
Thermal time constant	T_{th}	min	2.4			
Mass primary part with standard encapsulation	m_{PS}	kg	23.0		33.0	
Mass primary part with thermo encapsulation	m_{PT}	kg	28.3		40.0	
Data liquid cooling						
Power loss to be dissipated	P_V	W	1,700		2,200	
Necessary coolant flow at P_V	Q_{min}	l/min	2.4		3.2	
Pressure loss at Q_{min}	Δp	bar	0.9		1.4	
Constant for determining the pressure drop with standard encapsulation	$K_{\Delta p}$	--	33.0			
Constant for determining the pressure drop with thermo coupling	$K_{\Delta p}$	--	40.0			
Maximum allowed inlet pressure	p_{max}	bar	10.0			
Latest amendment: 2012-09-12						

Fig.4-54: MLP200A. MLP200B - Technical data

4.7.2 Motor Characteristic Curves MLP200A

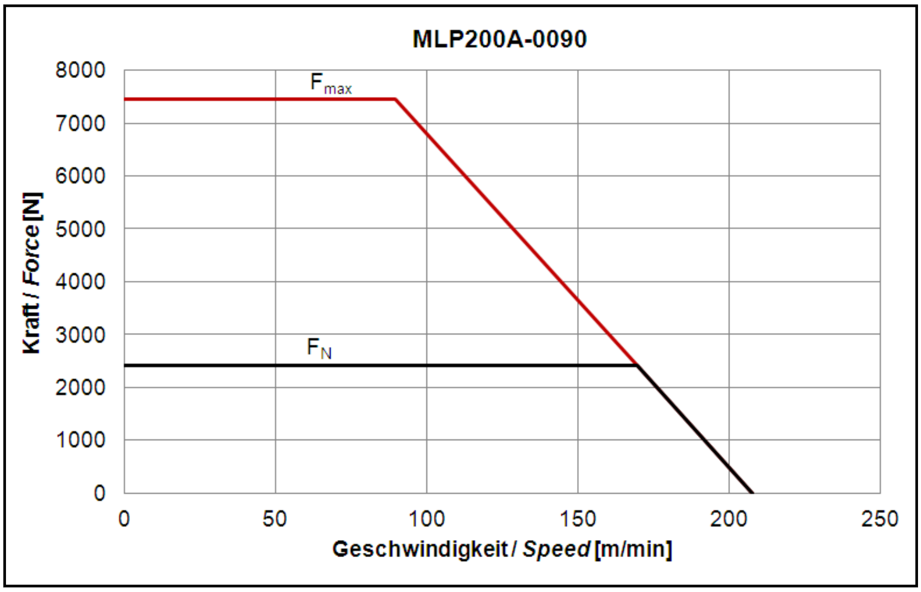


Fig.4-55: Motor characteristic curves MLP200A-0090

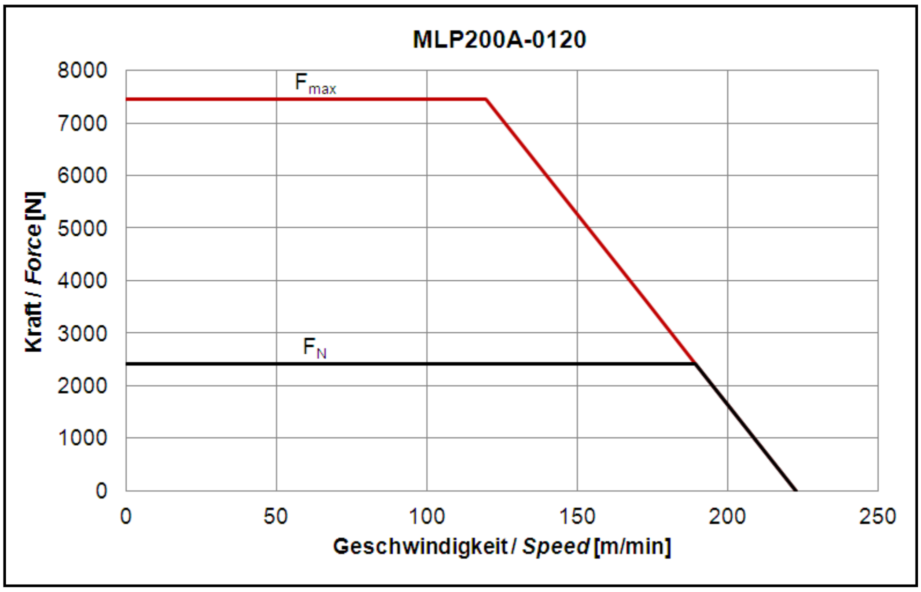


Fig.4-56: Motor characteristic curves MLP200A-0120

4.7.3 Motor Characteristic Curves MLP200B

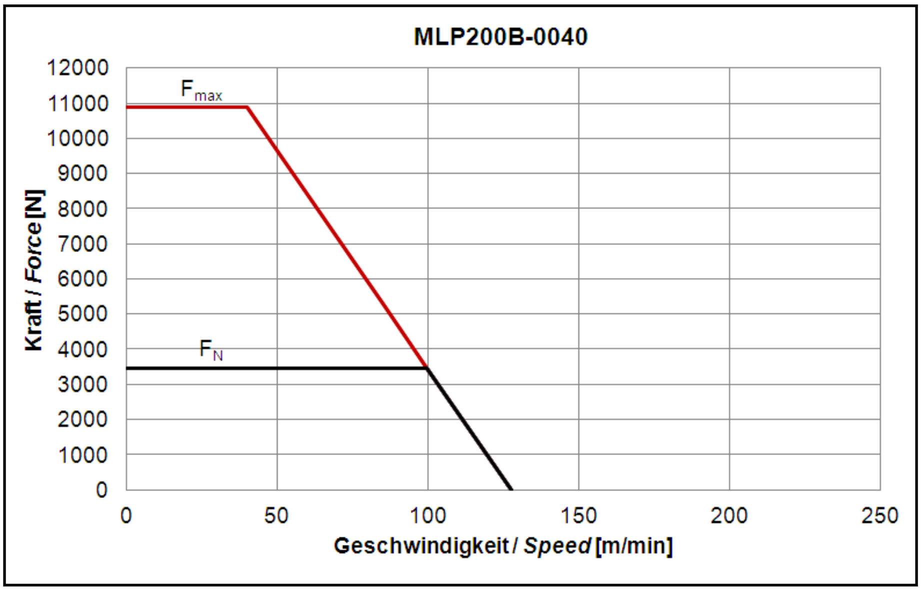


Fig.4-57: Motor characteristic curves MLP200B-0040

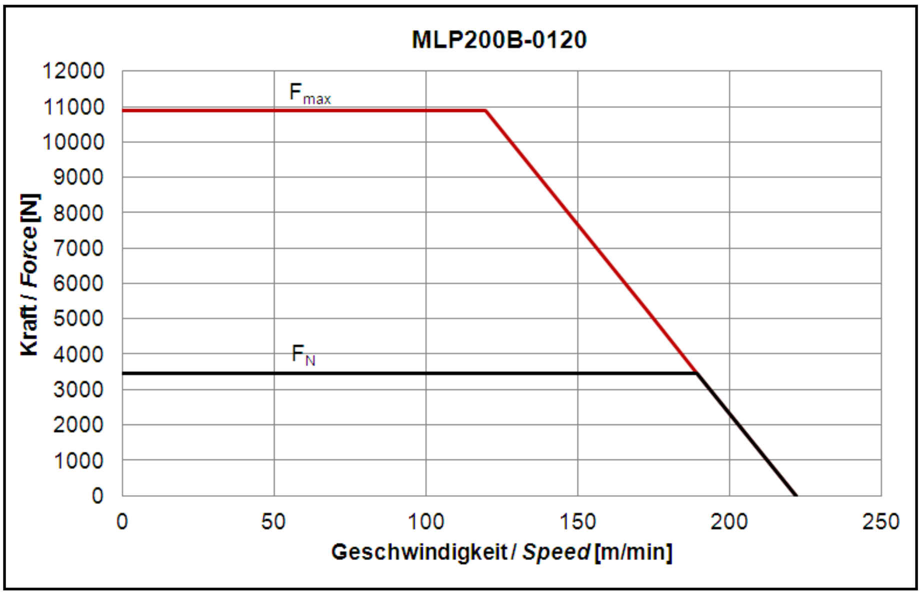


Fig.4-58: Motor characteristic curves MLP200B-0120

4.7.4 Data MLP200C

Parameter	Symbol	Unit	MLP200		
Frame Length			C		
Winding			0090	0120	0170
Maximum force	F_{max}	N	14250.0		
Continuous nominal force	F_N	N	4460.0		
Maximum current	$I_{max(rms)}$	A	117.9	165.6	162.6
Rated current	I_N	A	22.9	28.4	35.6
Maximum velocity at F_{max}	v_{Fmax}	m/min	90	120	170
Nominal velocity	v_N	m/min	170	190	220
Force constant	K_{FN}	N/A	194.10	157.20	125.30
Voltage constant	K_{EMK}	Vs/m	112.5	90.7	72.3
Winding resistance at 20 °C	R_{12}	Ohm	2.64	1.76	1.08
Winding inductivity	L_{12}	mH	13.6	9.0	5.7
Power wire cross-section	A	mm^2	4.0	6.0	10.0
Pole width	t_p	mm	37.5		
Attractive force	F_{ATT}	N	20,500.0		
Thermal time constant	T_{th}	min	2.4		
Mass primary part with standard encapsulation	m_{PS}	kg	42.0		
Mass primary part with thermo encapsulation	m_{PT}	kg	50.7		
Data liquid cooling					
Power loss to be dissipated	P_V	W	2,700		
Necessary coolant flow at P_V	Q_{min}	l/min	3.9		
Pressure loss at Q_{min}	Δp	bar	2.0		
Constant for determining the pressure drop with standard encapsulation	$K_{\Delta p}$	--	42.0		
Constant for determining the pressure drop with thermo coupling	$K_{\Delta p}$	--	50.7		
Maximum allowed inlet pressure	p_{max}	bar	10.0		
Latest amendment: 2012-09-12					

Fig.4-59: MLP200C - Technical data

4.7.5 Motor Characteristic Curves MLP200C

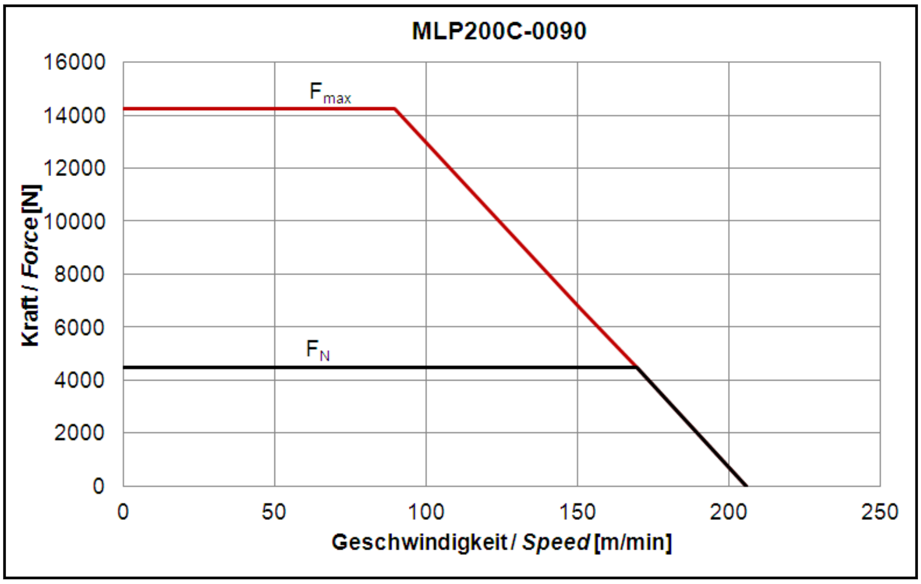


Fig.4-60: Motor characteristic curves MLP200C-0090

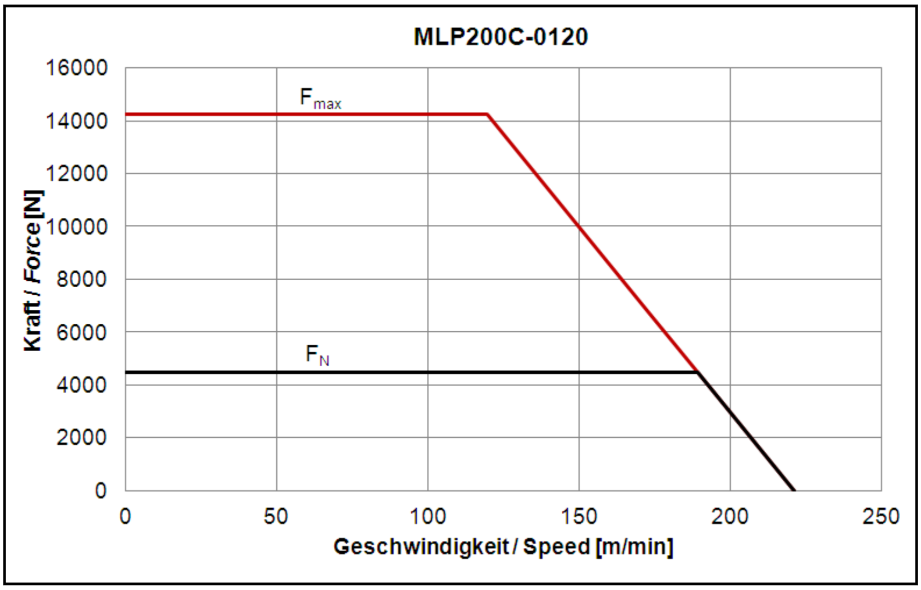


Fig.4-61: Motor characteristic curves MLP200C-0120

Technical Data IndraDyn L

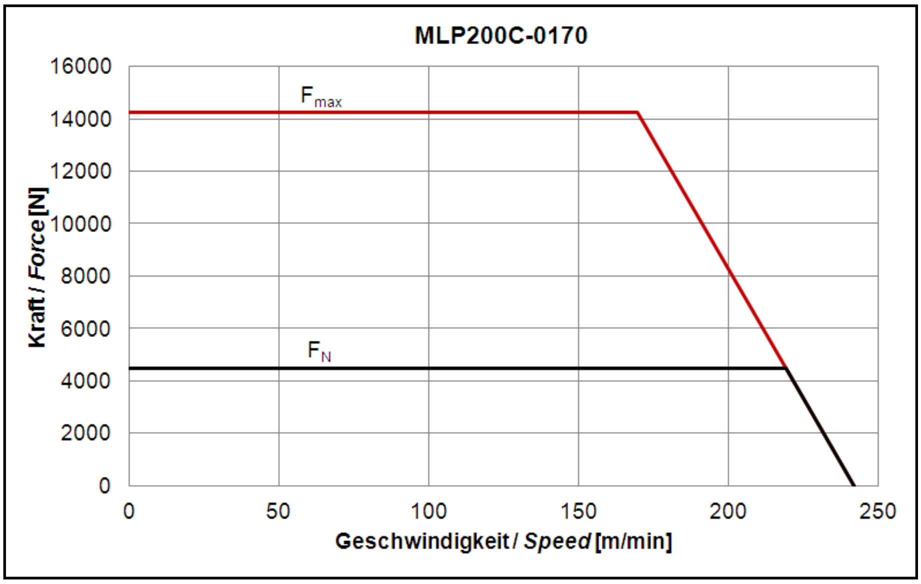


Fig.4-62: Motor characteristic curves MLP200C-0170

4.7.6 Data MLP200D

Parameter	Symbol	Unit	MLP200			
Frame Length			D			
Winding			0035	0060	0100	0120
Maximum force	F_{max}	N	16,500.0	17,750.0		
Continuous nominal force	F_N	N	5,560.0			
Maximum current	$I_{max(rms)}$	A	90.0	126.2	204.4	201.5
Rated current	I_N	A	20.2	25.2	44.8	47.5
Maximum velocity at F_{max}	v_{Fmax}	m/min	35	60	100	120
Nominal velocity	v_N	m/min	105	140	180	190
Force constant	K_{FN}	N/A	275.40	220.40	124.30	117.30
Voltage constant	K_{EMK}	Vs/m	159.0	127.2	71.7	67.6
Winding resistance at 20 °C	R_{12}	Ohm	4.0	2.74	0.88	0.74
Winding inductivity	L_{12}	mH	23.9	13.7	4.5	4.1
Power wire cross-section	A	mm^2	4.0		10.0	
Pole width	t_p	mm	37.5			
Attractive force	F_{ATT}	N	25,400.0			
Thermal time constant	T_{th}	min	2.4			
Mass primary part with standard encapsulation	m_{PS}	kg	51.0			
Mass primary part with thermo encapsulation	m_{PT}	kg	61.3			
Latest amendment: 2012-09-12						

Parameter	Symbol	Unit	MLP200			
Frame Length			D			
Winding			0035	0060	0100	0120
Data liquid cooling						
Power loss to be dissipated	P_V	W	4,969			
Necessary coolant flow at P_V	Q_{min}	l/min	8.0			
Pressure loss at Q_{min}	Δp	bar	2.4			
Constant for determining the pressure drop with standard encapsulation	$K_{\Delta p}$	--	51.0			
Constant for determining the pressure drop with thermo coupling	$K_{\Delta p}$	--	61.3			
Maximum allowed inlet pressure	p_{max}	bar	10.0			
Latest amendment: 2012-09-12						

Fig.4-63: MLP200D - Technical data

4.7.7 Motor Characteristic Curves MLP200D

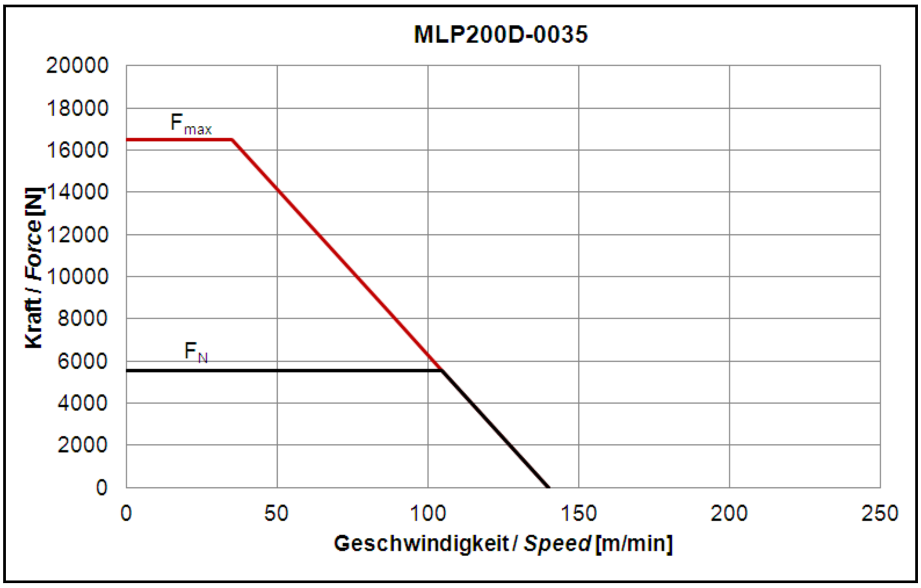


Fig.4-64: Motor characteristic curves MLP200D-0035

Technical Data IndraDyn L

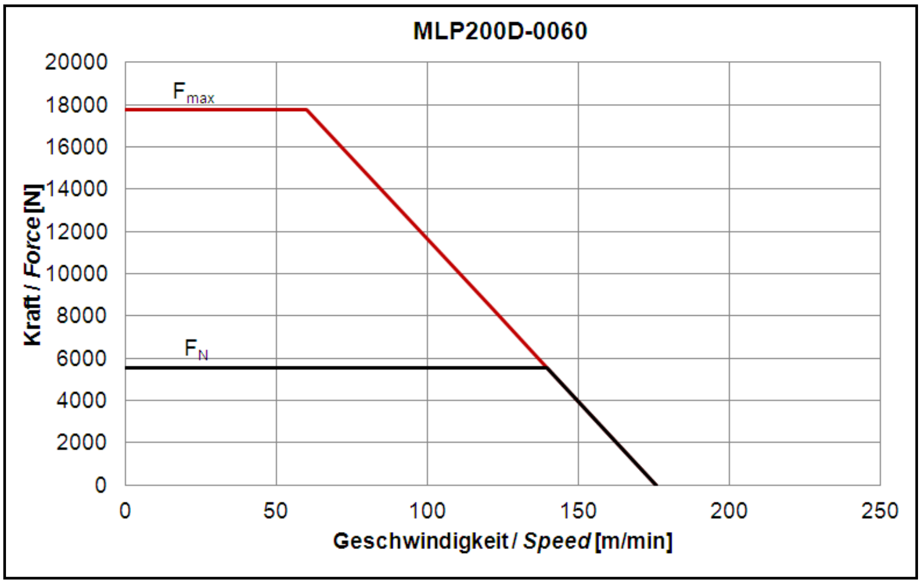


Fig.4-65: Motor characteristic curves MLP200D-0060

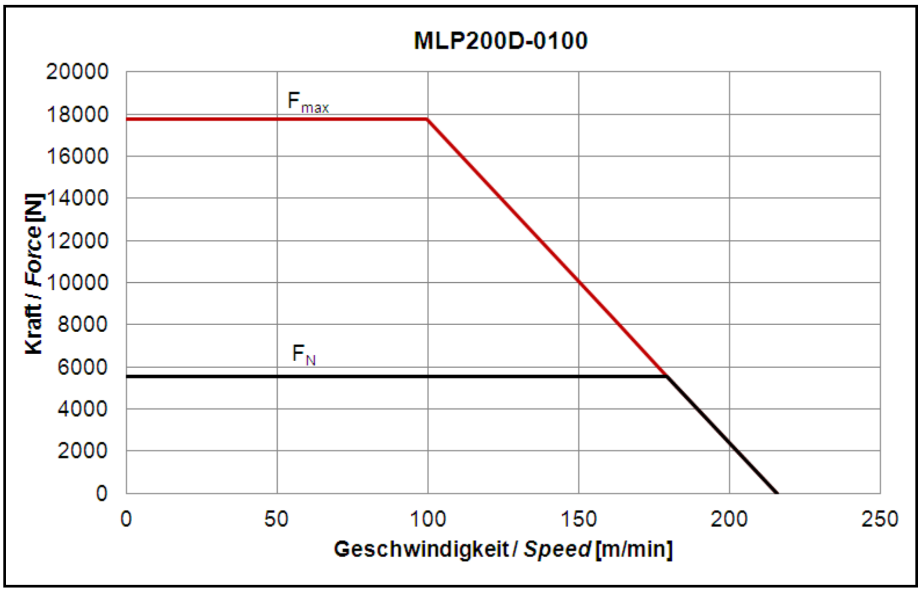


Fig.4-66: Motor characteristic curves MLP200D-0100

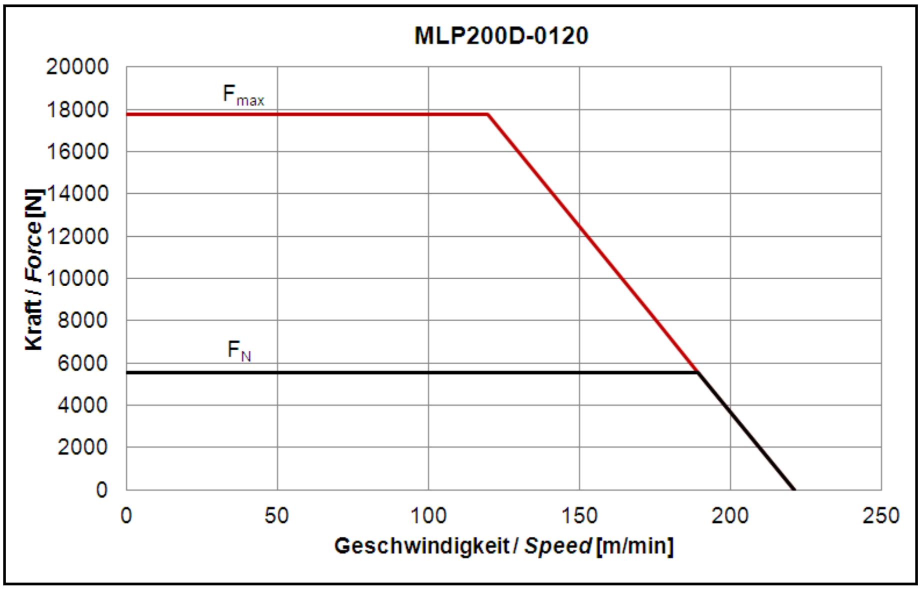


Fig.4-67: Motor characteristic curves MLP200D-0120

4.7.8 Data MLS200

Designation	Symbol	Unit	MLS200S-3A-0150-NNNN	MLS200S-3A-0450-NNNN	MLS200S-3A-0600-NNNN
Secondary part mass	m_S	kg	4.0	12.1	16.1
Latest amendment: 2008-10-29					

Fig.4-68: MLS200 - Technical data

4.8 Technical Data - Frame Size MLP300

4.8.1 Data MLP300A, MLP300B

Parameter	Symbol	Unit	MLP300			
Frame Length			A		B	
Winding			0090	0120	0070	0120
Maximum force	F_{max}	N	11,000.0		16,300.0	
Continuous nominal force	F_N	N	3,350.0		5,150.0	
Maximum current	$I_{max(rms)}$	A	99.3	129.9	141.9	223.5
Rated current	I_N	A	17.2	21.6	28.4	38.2
Maximum velocity at F_{max}	v_{Fmax}	m/min	90	120	70	120
Nominal velocity	v_N	m/min	160	190	140	190
Force constant	K_{FN}	N/A	195.40	154.90	181.60	134.10
Voltage constant	K_{EMK}	Vs/m	112.8	89.4	104.8	77.9
Winding resistance at 20 °C	R_{12}	Ohm	3.05	2.0	2.2	1.3
Winding inductivity	L_{12}	mH	14.9	9.3	12.0	6.7
Power wire cross-section	A	mm^2	2.5	4.0		6.0
Pole width	t_p	mm	37.5			
Attractive force	F_{ATT}	N	16,000.0		23,400.0	
Thermal time constant	T_{th}	min	2.4			
Mass primary part with thermo encapsulation	m_{PT}	kg	40.8		58.3	
Data liquid cooling						
Power loss to be dissipated	P_V	W	2,200		2,900	
Necessary coolant flow at P_V	Q_{min}	l/min	3.2		4.2	
Pressure loss at Q_{min}	Δp	bar	1.4		2.3	
Constant for determining the pressure drop with thermo coupling	$K_{\Delta p}$	--	58.3			
Maximum allowed inlet pressure	p_{max}	bar	10.0			
Latest amendment: 2012-09-12						

Fig.4-69: MLP300A, MLP300B - Technical data

4.8.2 Motor Characteristic Curves Frame Size MLP300A, MLP300B

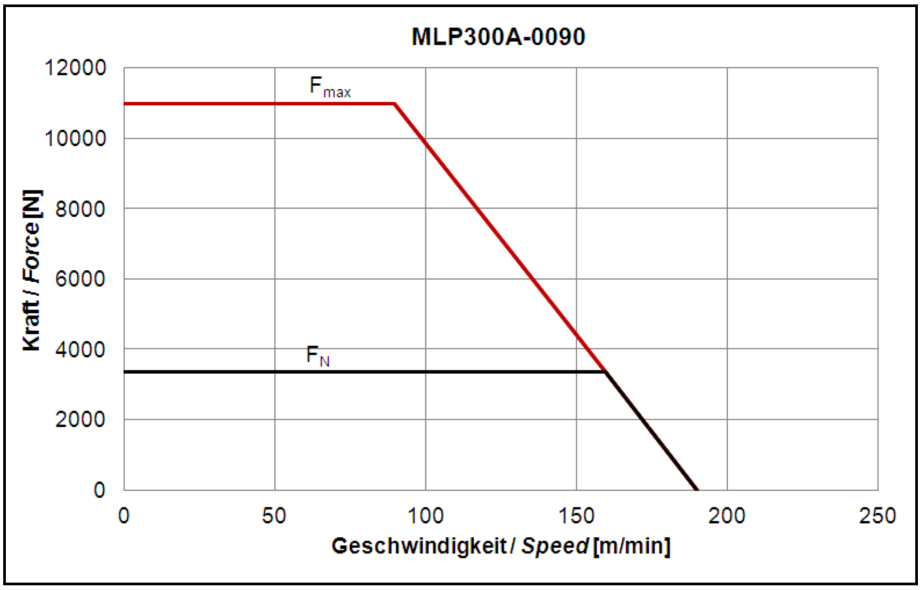


Fig.4-70: Motor characteristic curves MLP300A-0090

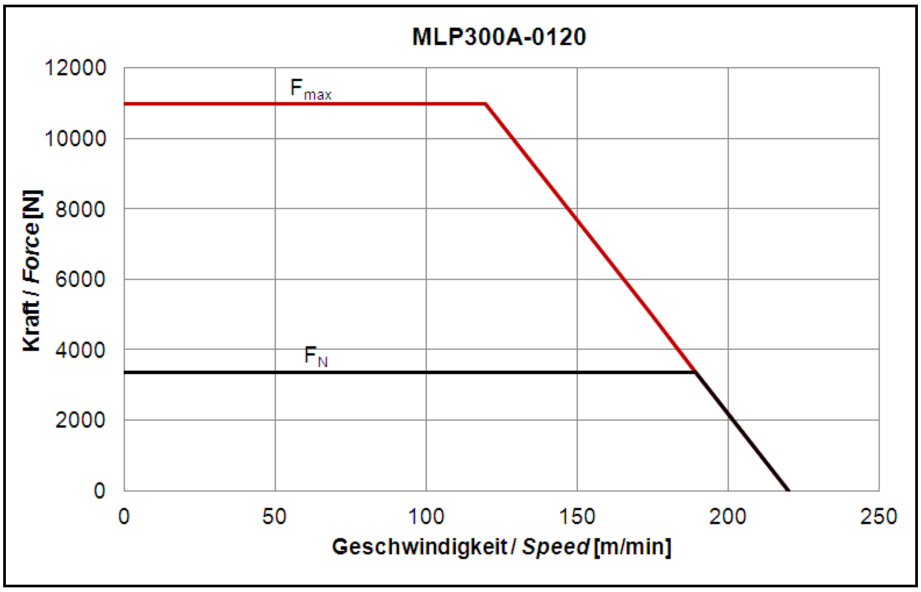


Fig.4-71: Motor characteristic curves MLP300A-0120

Technical Data IndraDyn L

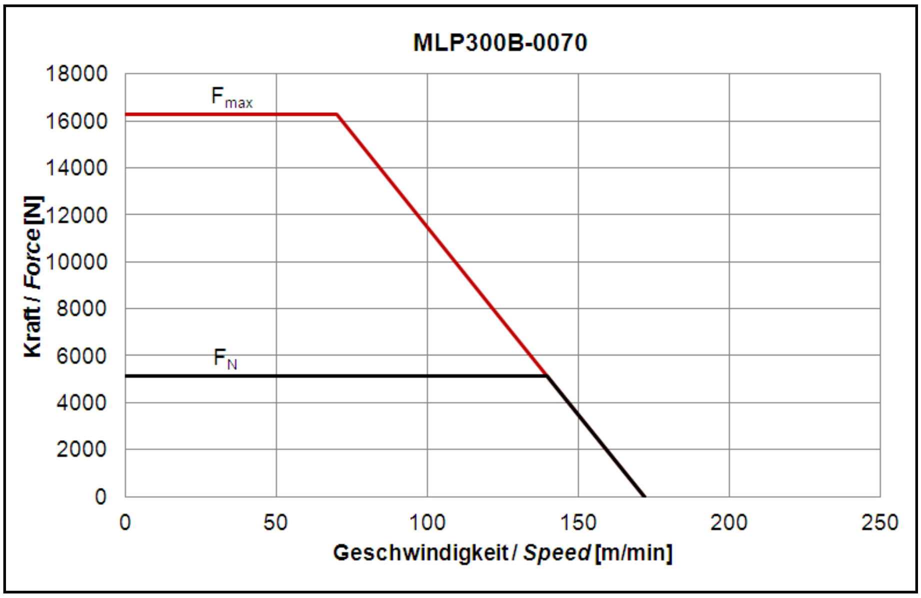


Fig.4-72: Motor characteristic curves MLP300B-0070

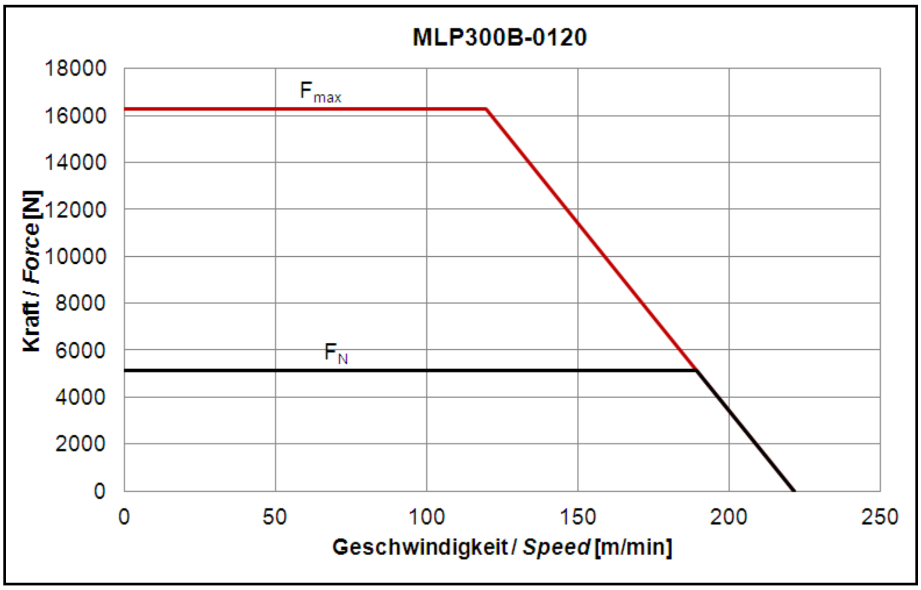


Fig.4-73: Motor characteristic curves MLP300B-0120

4.8.3 Data MLP300C

Parameter	Symbol	Unit	MLP300		
Frame Length			C		
Winding			0060	0090	0120
Maximum force	F_{max}	N	21,500.0		
Continuous nominal force	F_N	N	6,720.0		
Maximum current	$I_{max(rms)}$	A	143.1	205.0	300.0
Rated current	I_N	A	29.6	35.8	45.2
Maximum velocity at F_{max}	v_{Fmax}	m/min	60	90	120
Nominal velocity	v_N	m/min	110	150	180
Force constant	K_{FN}	N/A	226.90	187.90	148.90
Voltage constant	K_{EMK}	Vs/m	130.9	108.4	85.9
Winding resistance at 20 °C	R_{12}	Ohm	2.4	1.56	1.02
Winding inductivity	L_{12}	mH	11.4	7.6	4.9
Power wire cross-section	A	mm^2	4.0	6.0	10.0
Pole width	t_p	mm	37.5		
Attractive force	F_{ATT}	N	30,700.0		
Thermal time constant	T_{th}	min	2.4		
Mass primary part with thermo encapsulation	m_{PT}	kg	74.9		
Data liquid cooling					
Power loss to be dissipated	P_V	W	3,200		
Necessary coolant flow at P_V	Q_{min}	l/min	4.6		
Pressure loss at Q_{min}	Δp	bar	2.8		
Constant for determining the pressure drop with thermo coupling	$K_{\Delta p}$	--	74.9		
Maximum allowed inlet pressure	p_{max}	bar	10.0		
Latest amendment: 2012-09-12					

Fig.4-74: MLP300C - technical data

Technical Data IndraDyn L

4.8.4 Motor Characteristic Curves MLP300C

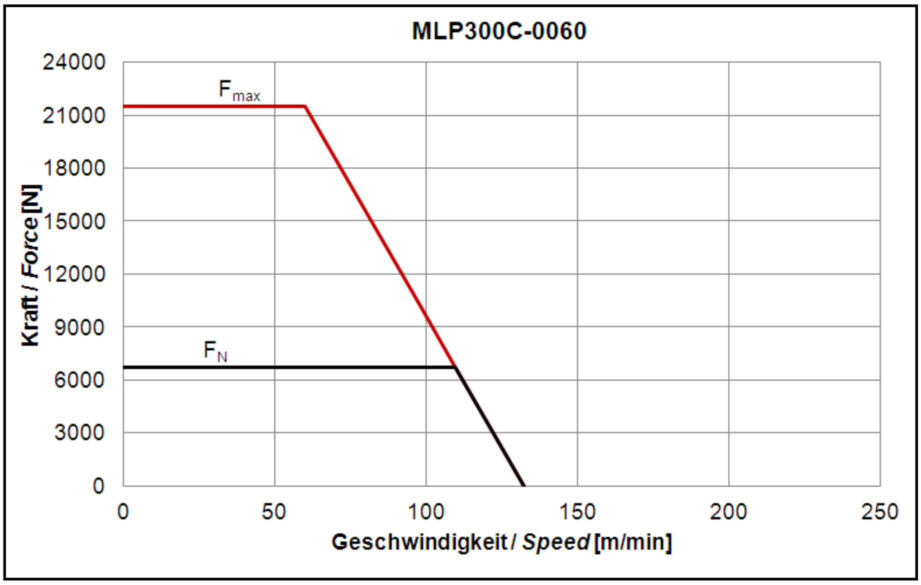


Fig.4-75: Motor characteristic curves MLP300C-0060

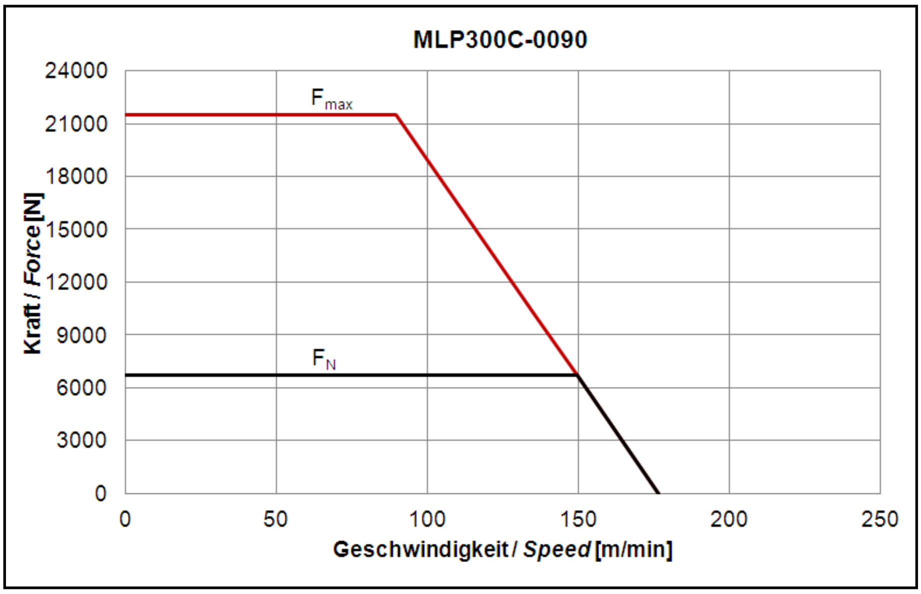


Fig.4-76: Motor characteristic curves MLP300C-0090

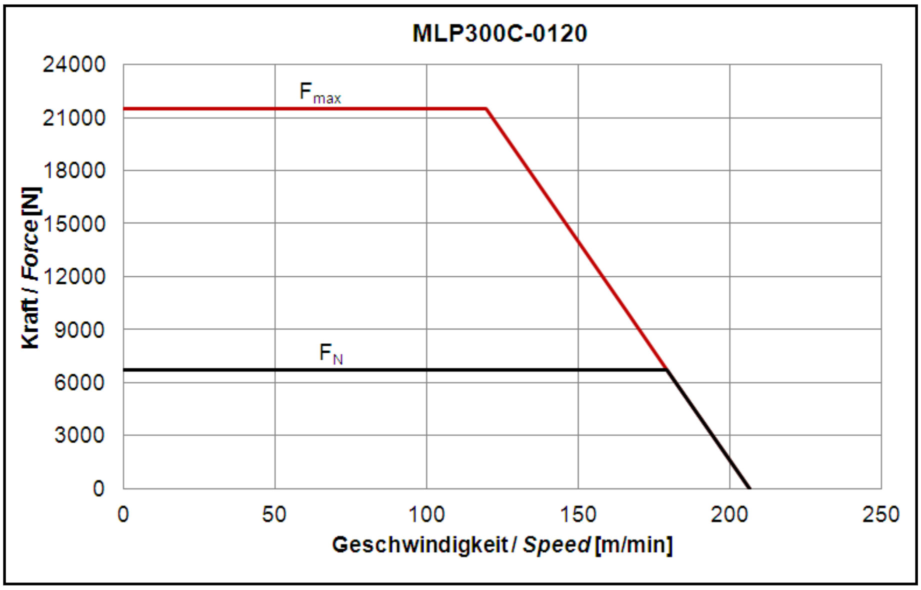


Fig.4-77: Motor characteristic curves MLP300C-0120

4.8.5 Data MLS300

Designation	Symbol	Unit	MLS300S-3A-0150-HNNN	MLS300S-3A-0450-HNNN	MLS300S-3A-0600-HNNN
Secondary part mass	m_S	kg	10.5	31.5	42.0
Latest amendment: 2008-10-29					

Fig.4-78: MLS300 - technical data

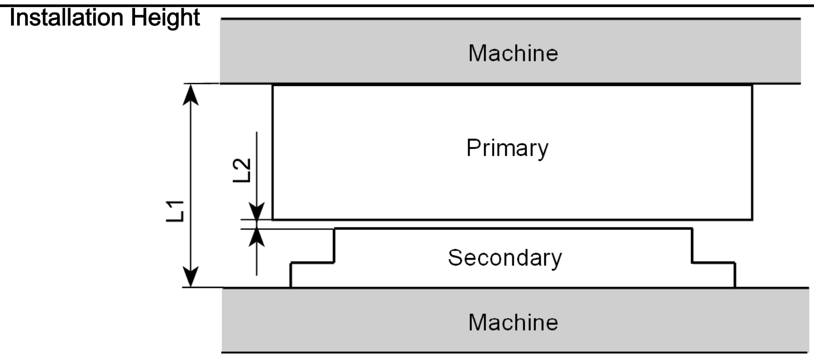
5 Dimensions, Installation Dimension and Tolerances

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). Thus, the specified size and tolerances of the air gap are maintained automatically – even if individual motor components are replaced.



Frame size Primary part	Design Primary part	Design Secondary part	Installation height L1	Measurable air gap L2
40 ... 200	Standard encapsulation		$61,4^{+0,1}$	$1,0^{+0,55}_{-0,4}$
300	Standard encapsulation		$72,5^{+0,1}$	$1,2^{+0,55}_{-0,4}$
		MLSxxxS-*		
040 ... 200	Thermal encapsulation		$73,9^{+0,1}$	$1,0^{+0,55}_{-0,4}$
300	Thermal encapsulation		$87,0^{+0,1}$	$1,2^{+0,55}_{-0,4}$

Fig.5-1: Mounting Sizes and Tolerances

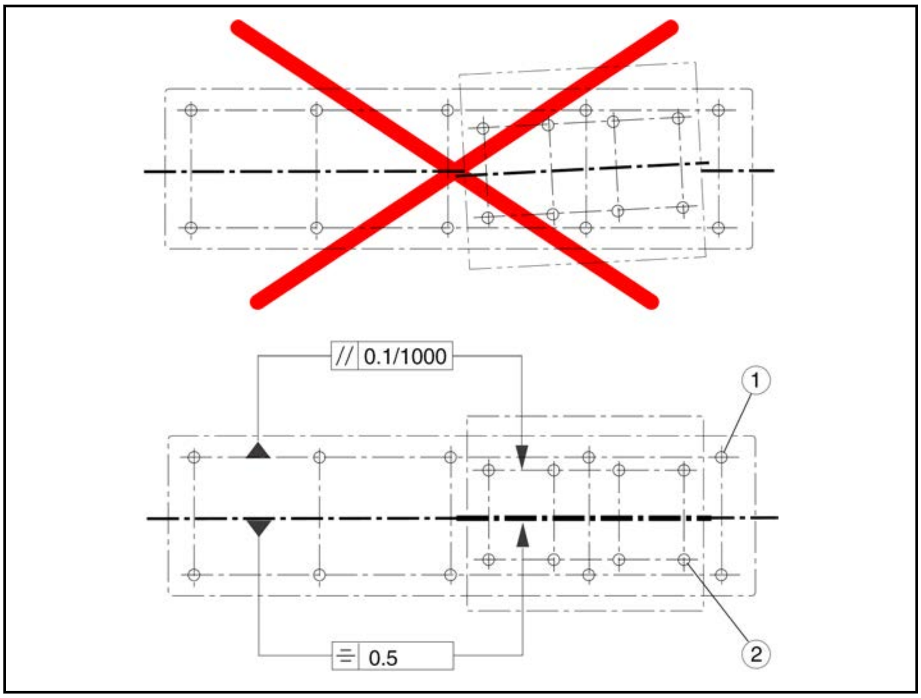
☞ The specified installation height with the corresponding tolerances has to be observed absolutely.

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 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

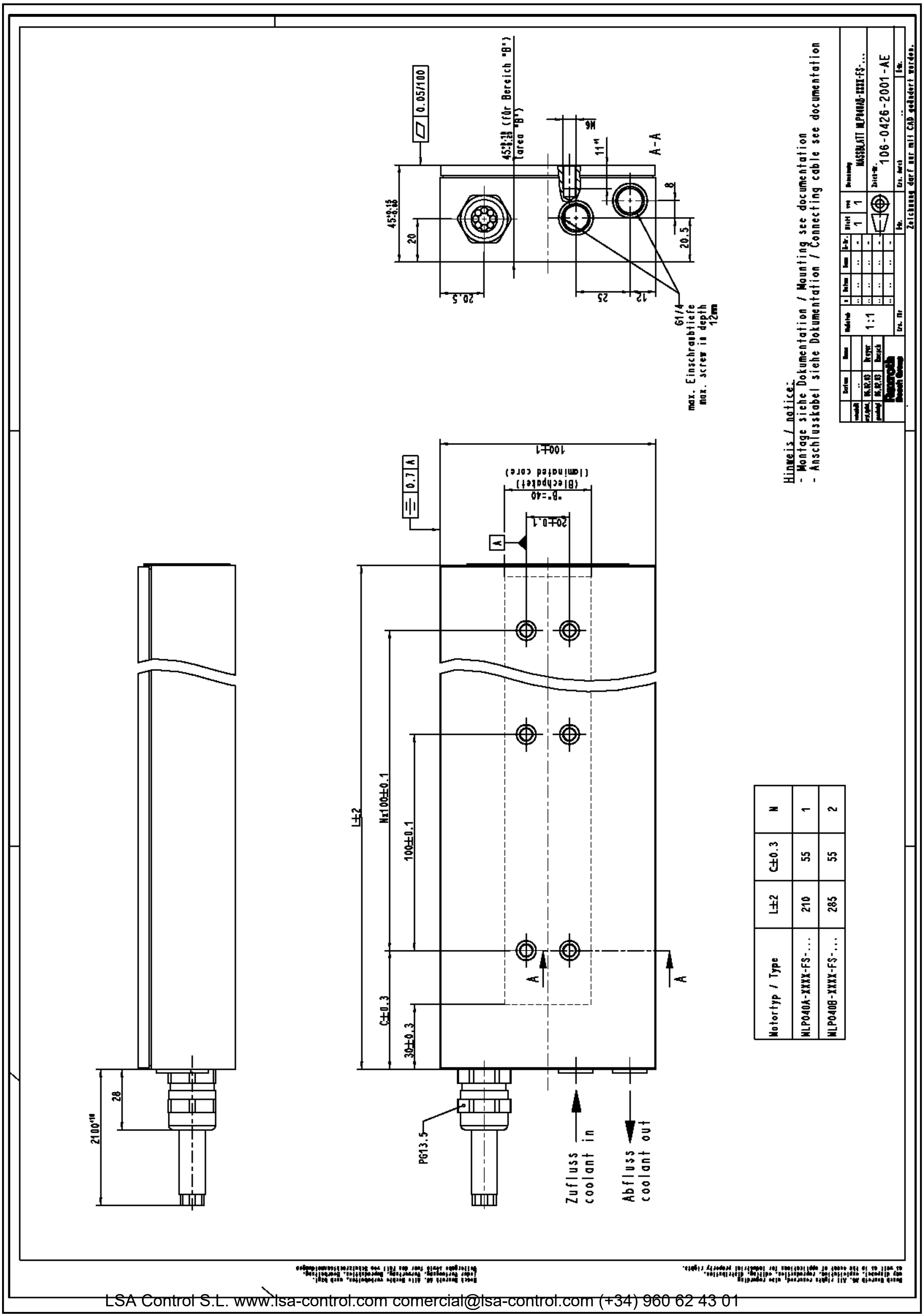
Fig.5-2: Parallelism and symmetry between the fastening holes for the primary part and the fastening threads for the secondary part

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

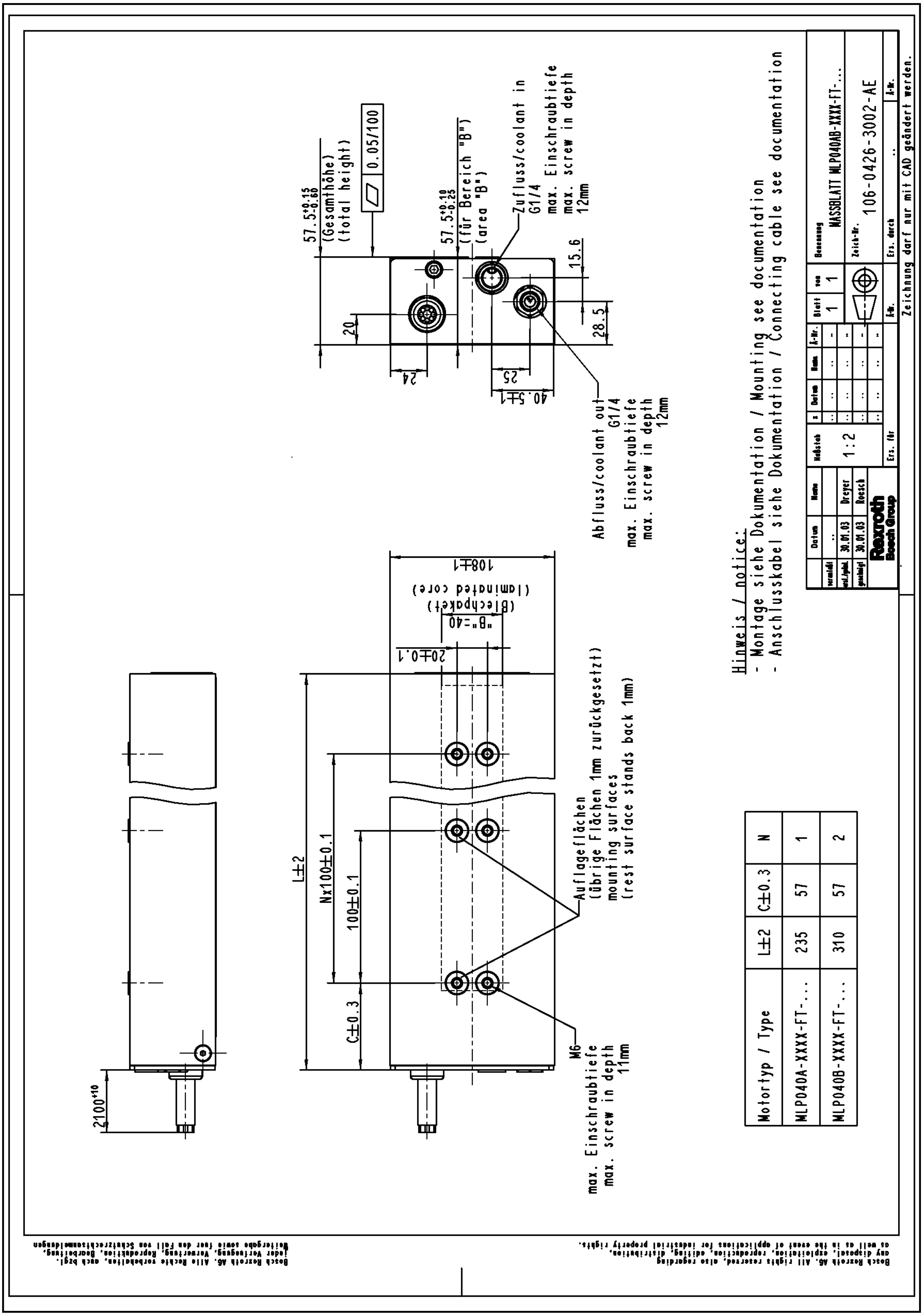
You will find further notes regarding assembly of primary and secondary parts under chapter 12 "Assembly" on page 231.

5.2 Dimension Sheets Frame Size 040

5.2.1 Primary Part MLP040 with Standard Encapsulation



5.2.2 Primary Part MLP040 with Thermo Encapsulation



Motortyp / Type	L±2	C±0.3	N
MLP040A-XXXX-FT-...	235	57	1
MLP040B-XXXX-FT-...	310	57	2

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

5.2.3 Secondary Part MLS040

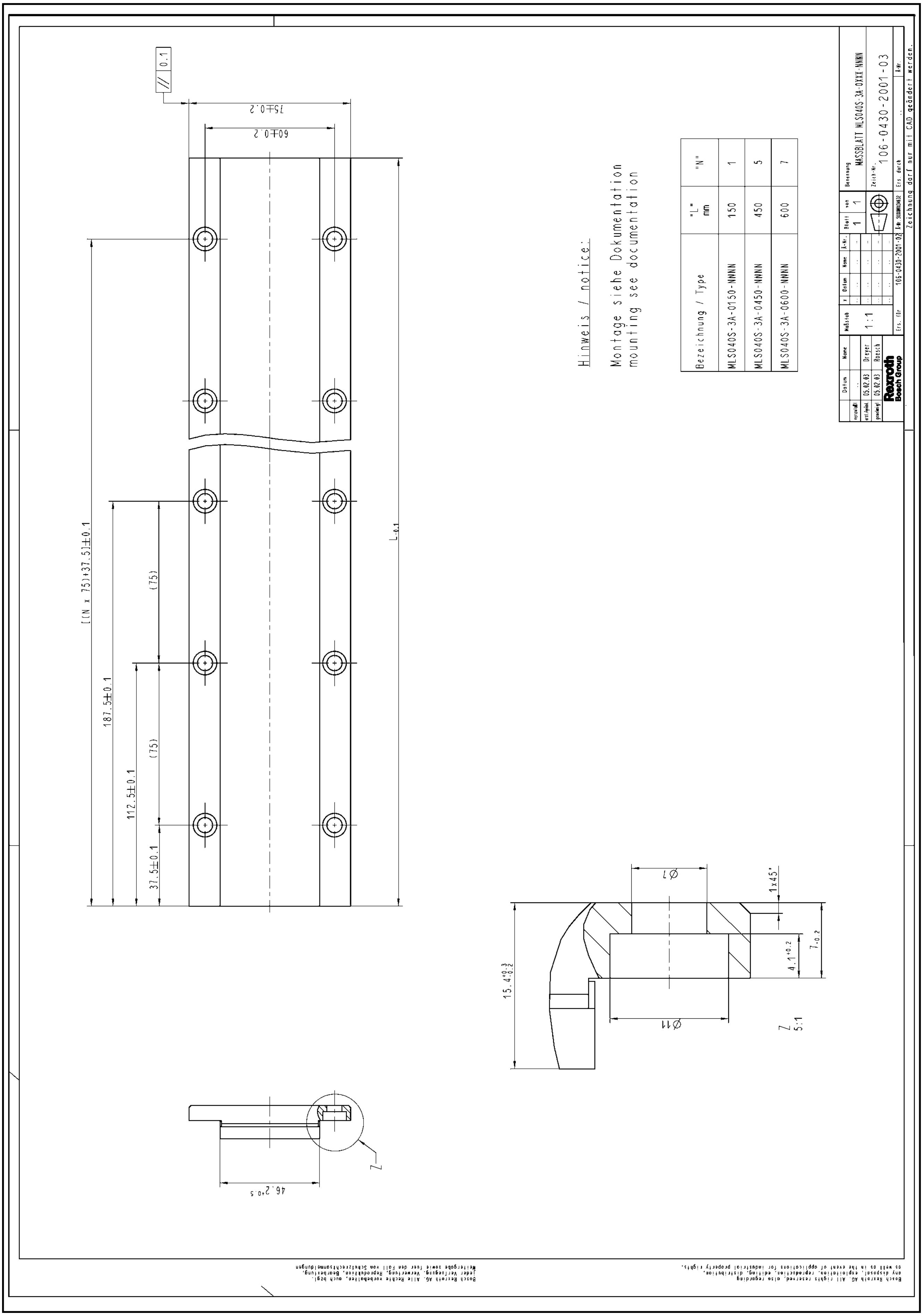
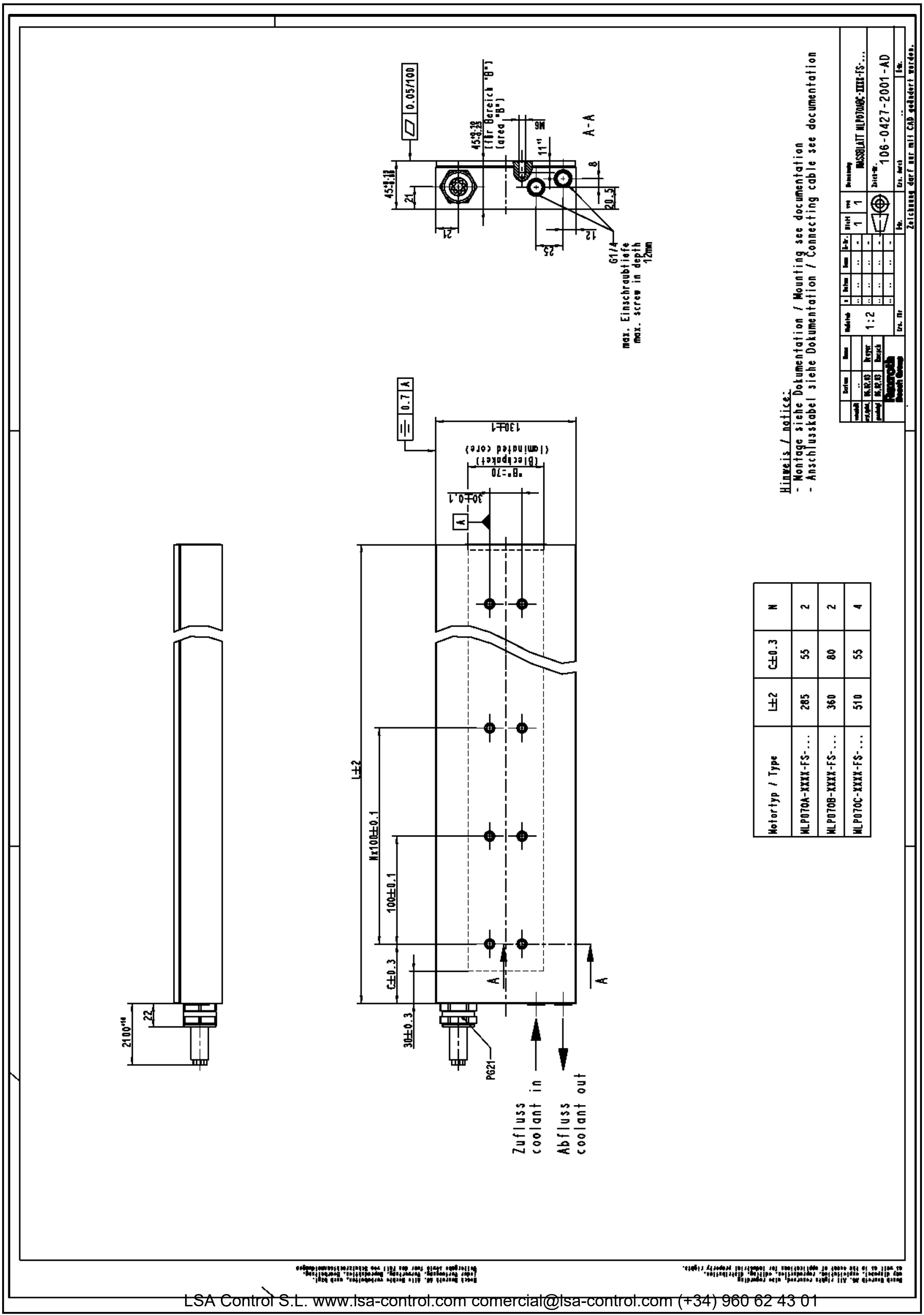


Fig.5-5: Secondary Part MLS040

Dimensions, Installation Dimension and Tolerances

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

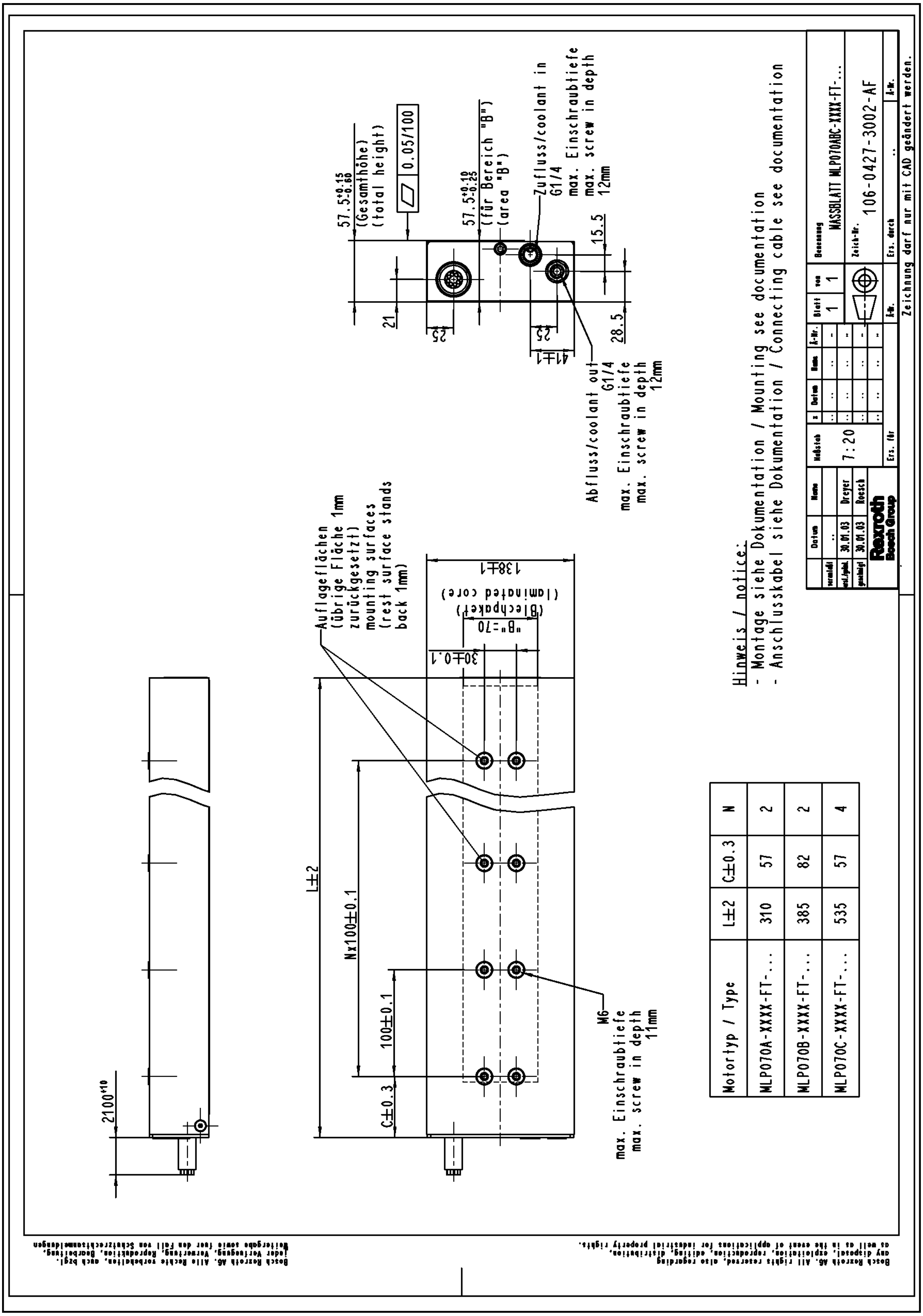


Fig.5-7: Primary Part MLP070 with Thermo Encapsulation

Dimensions, Installation Dimension and Tolerances

5.3.3 Secondary Part MLS070

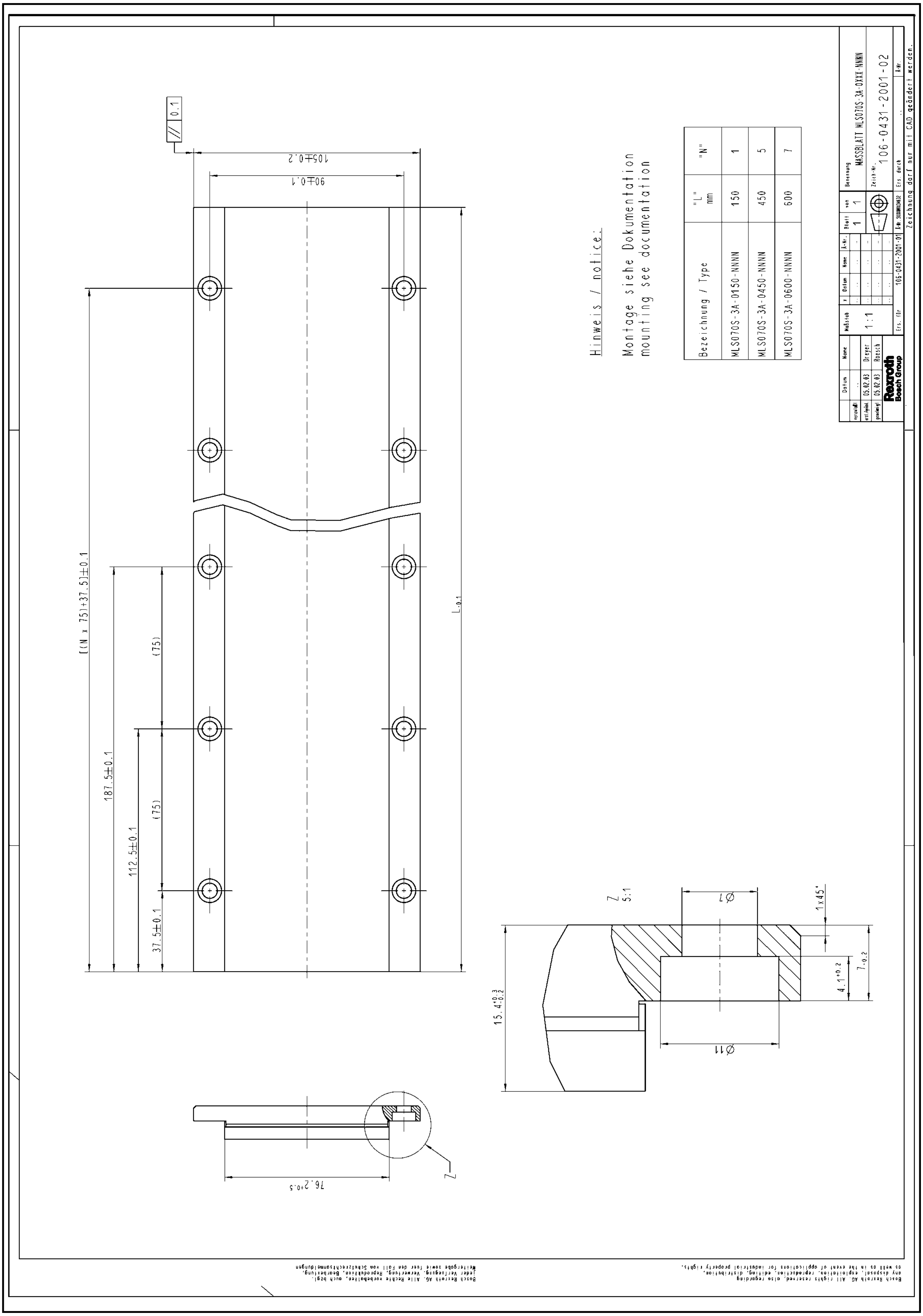
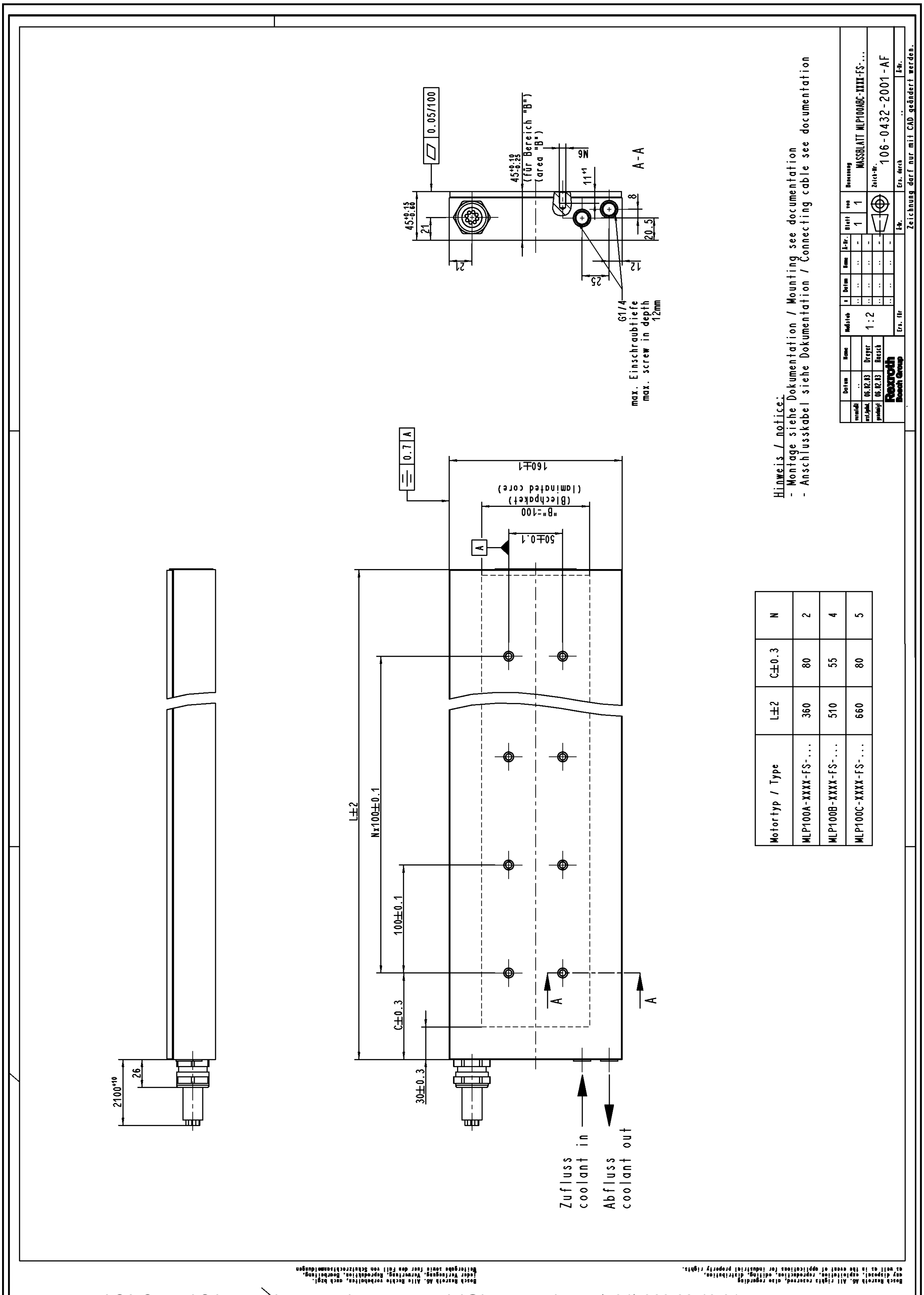


Fig.5-8: Secondary Part MLS070

5.4 Dimension Sheets Frame Size 100

5.4.1 Primary Part MLP100 with Standard Encapsulation



Motortyp / Type	L±2	C±0.3	N
MLP100A-XXXX-FS-...	360	80	2
MLP100B-XXXX-FS-...	510	55	4
MLP100C-XXXX-FS-...	660	80	5

Dimensions, Installation Dimension and Tolerances

5.4.2 Primary Part MLP100 with Thermo Encapsulation

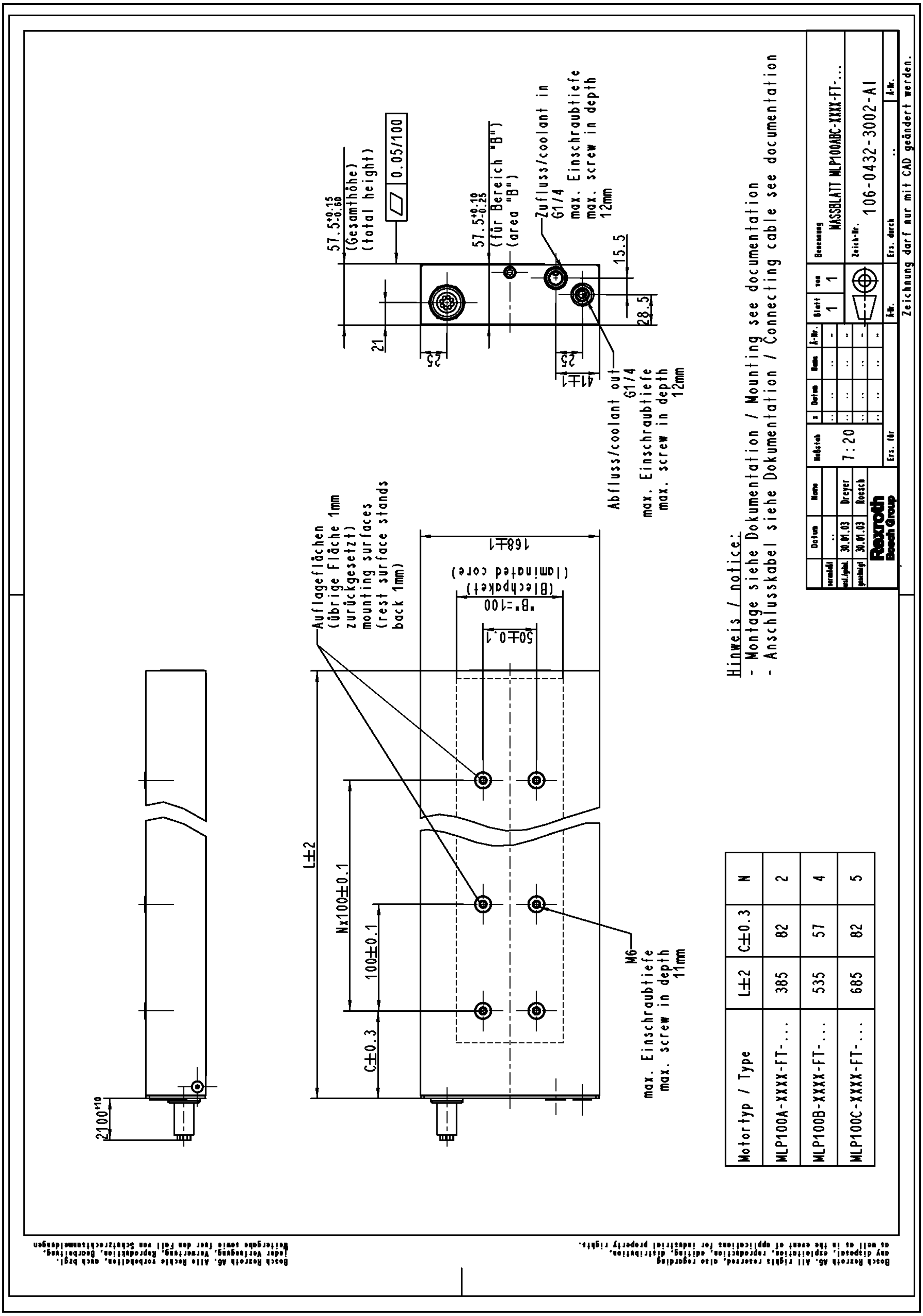


Fig.5-10: Primary Part MLP100 with Thermo Encapsulation

5.4.3 Secondary Part MLS100

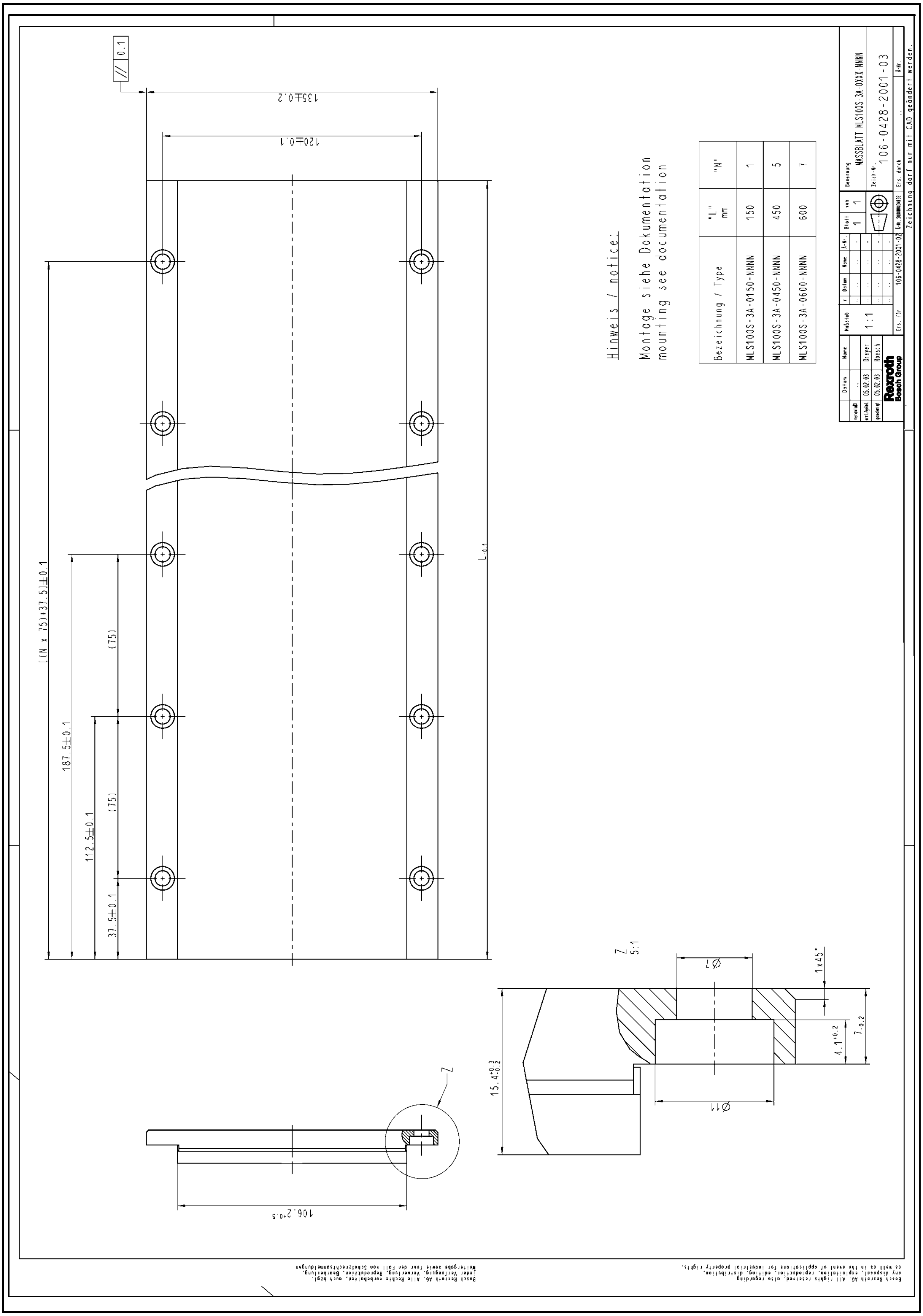
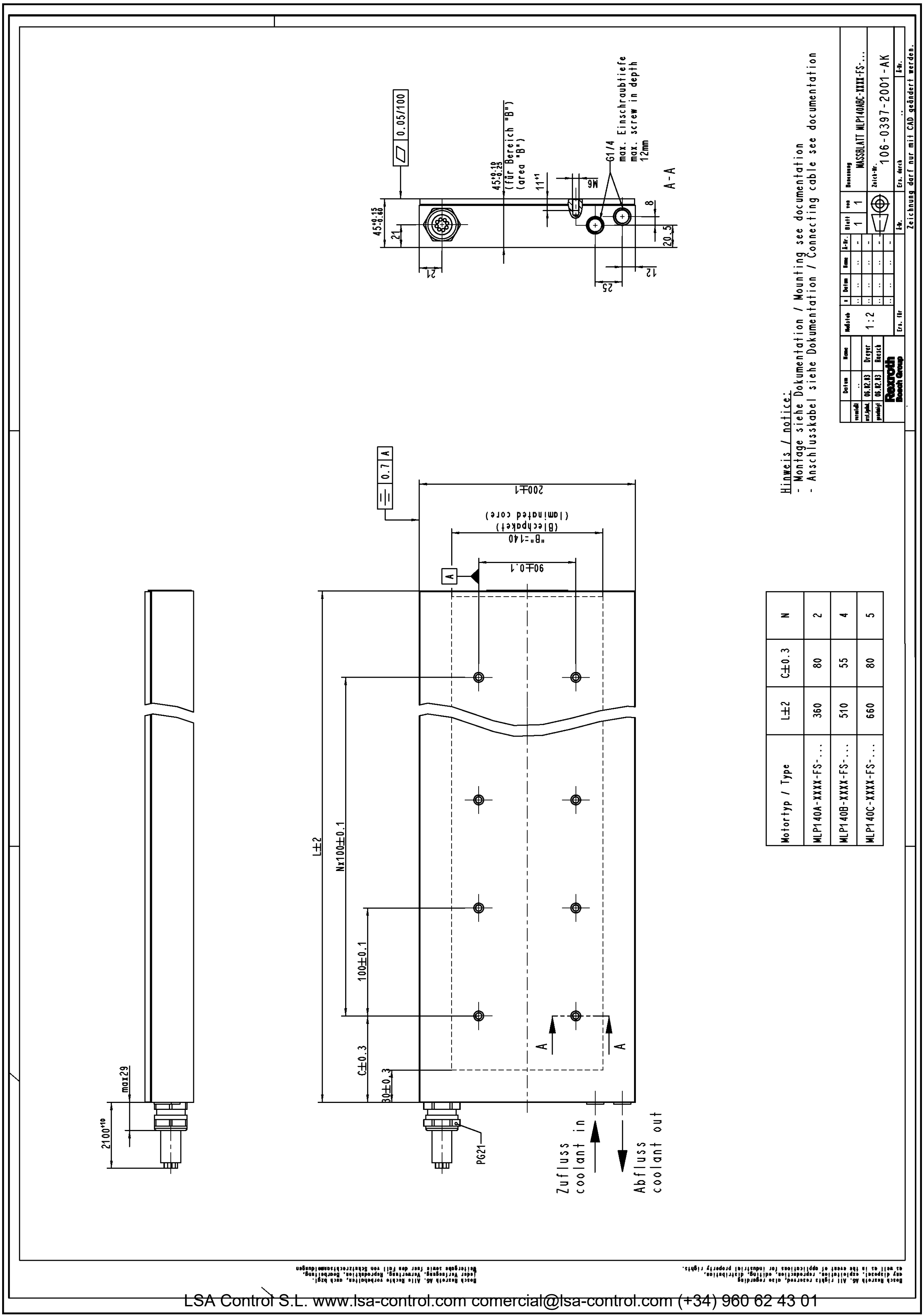


Fig.5-11: Secondary Part MLS100

Dimensions, Installation Dimension and Tolerances

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

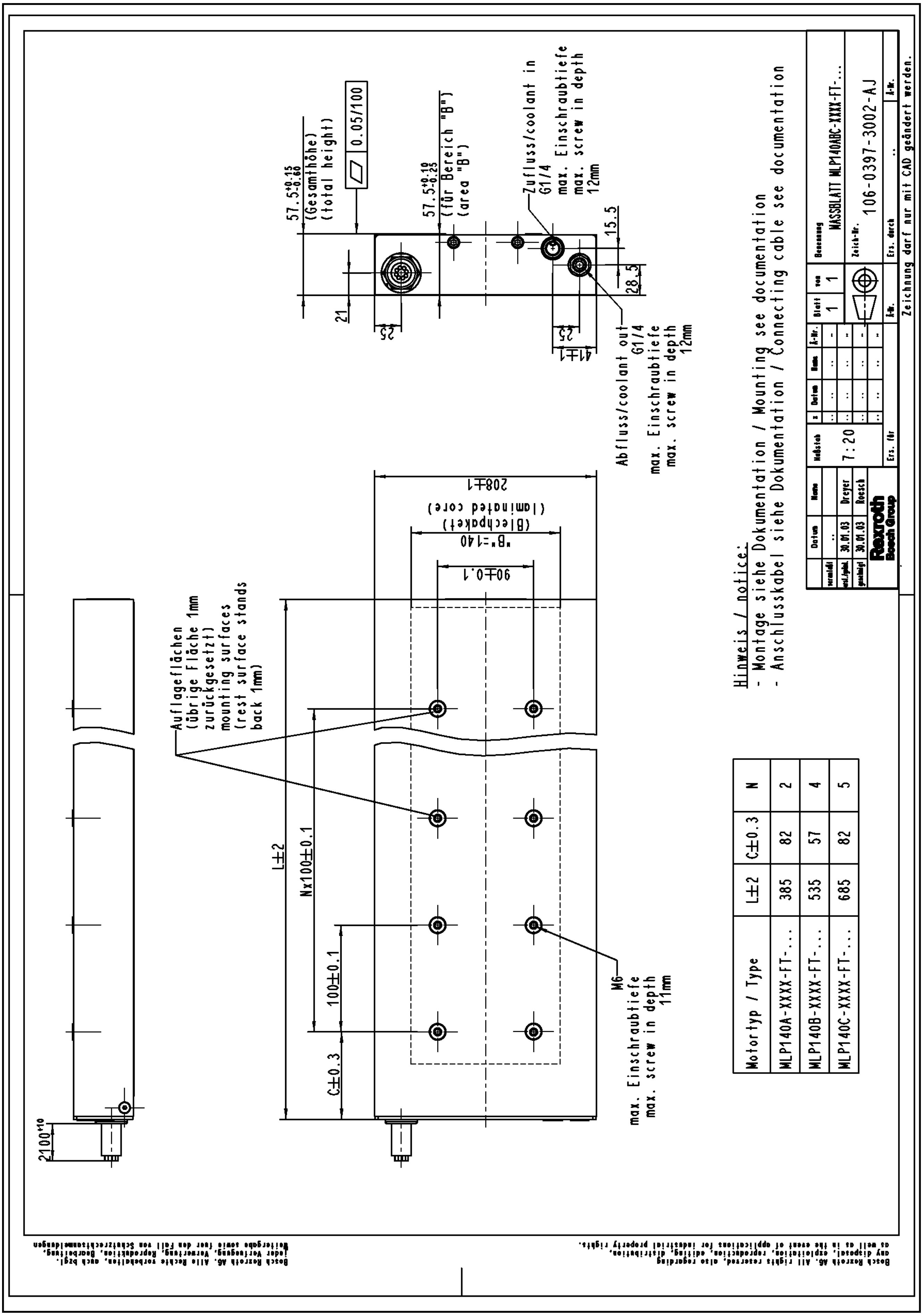


Fig.5-13: Primary Part MLP140 with Thermo Encapsulation

Dimensions, Installation Dimension and Tolerances

5.5.3 Secondary Part MLS140

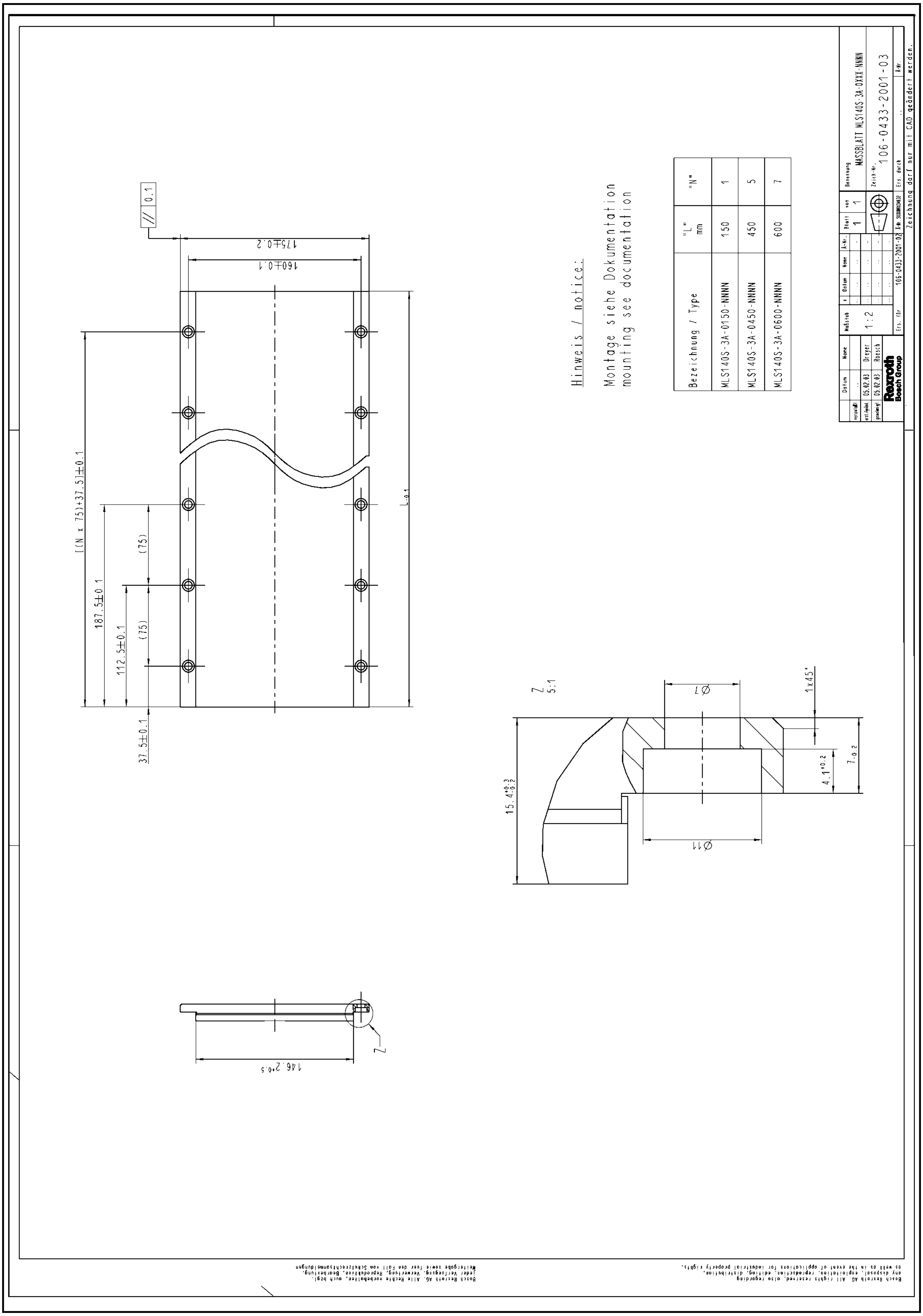
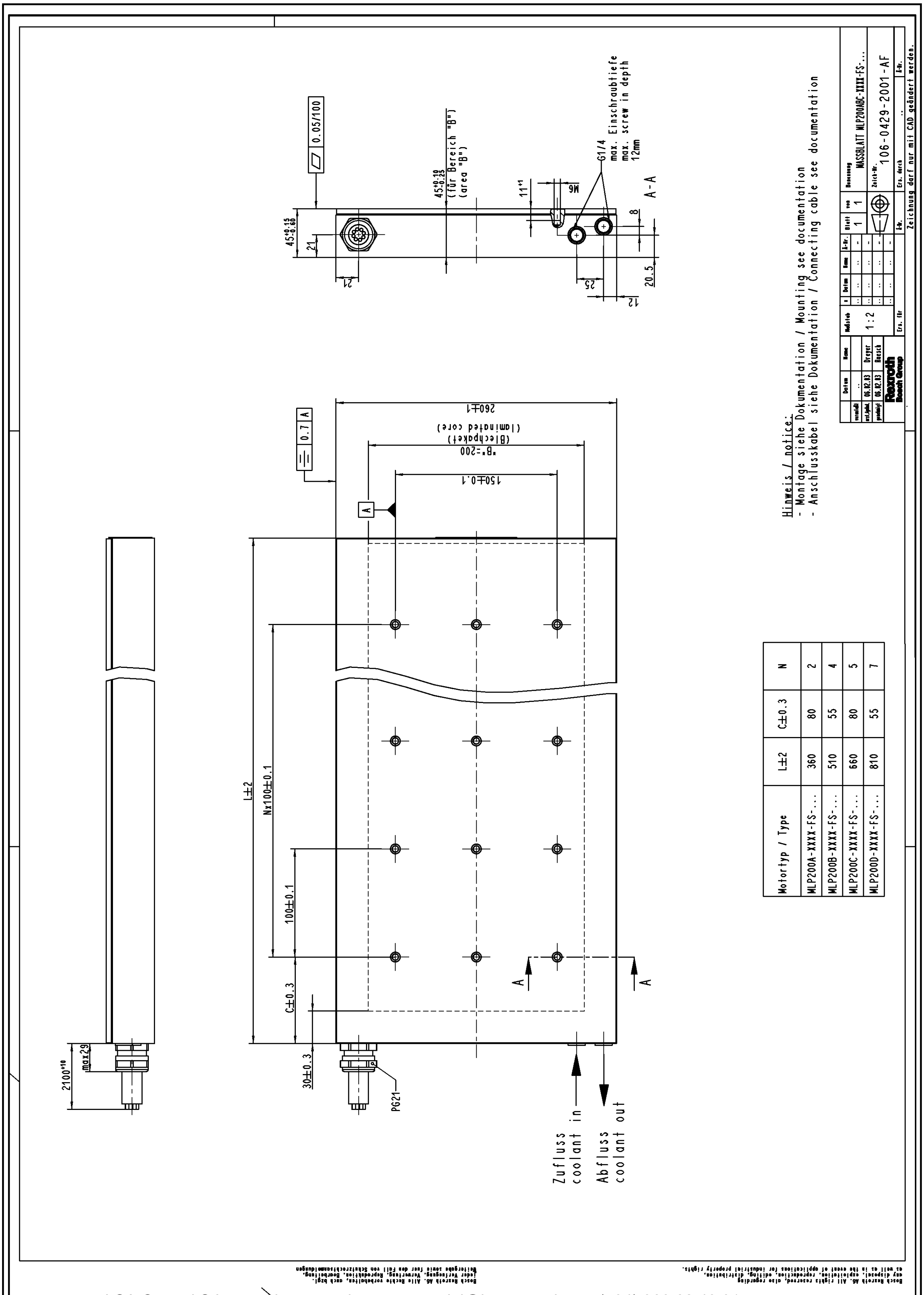


Fig.5-14: Secondary Part MLS140

5.6 Dimension Sheets Frame Size 200

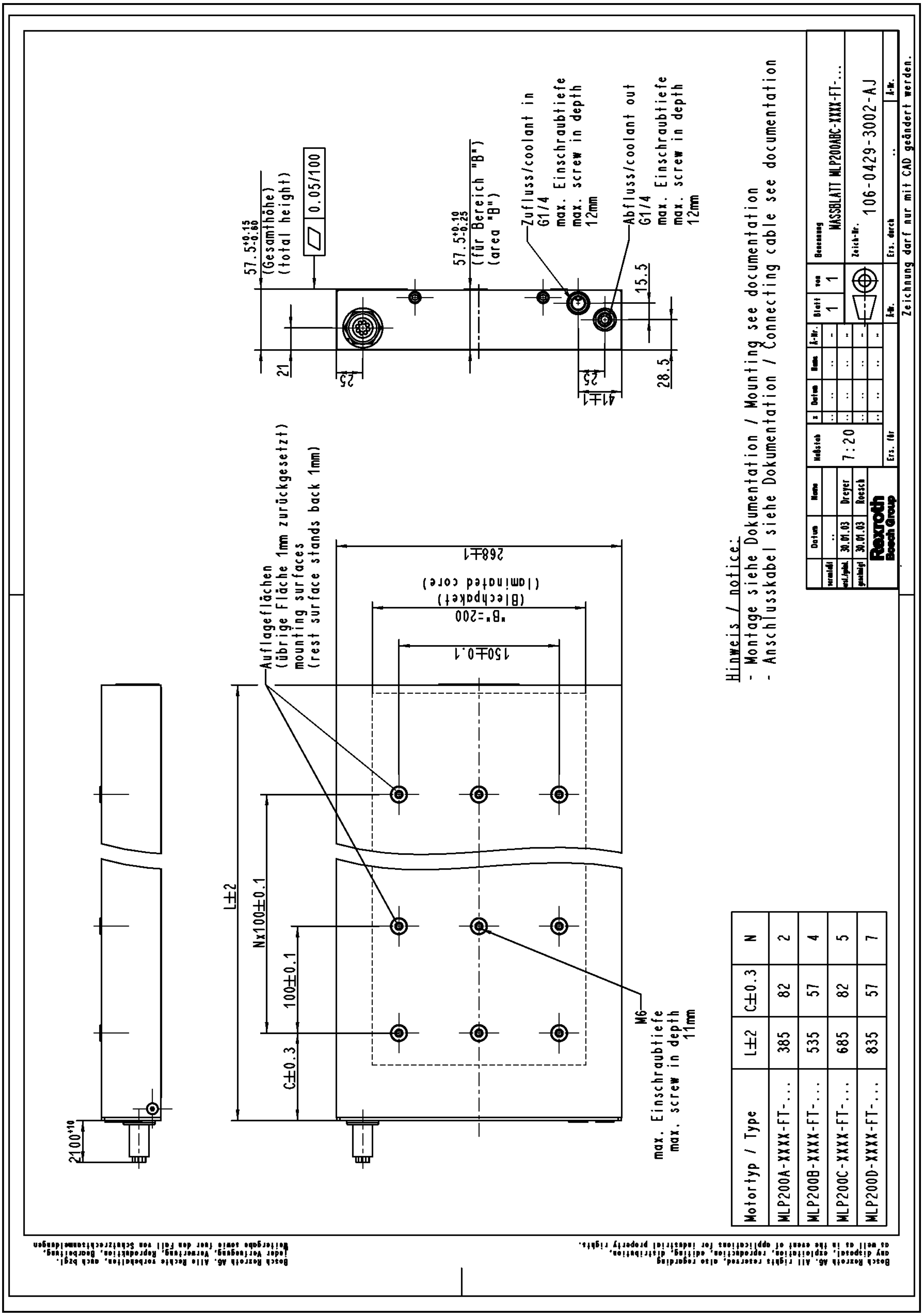
5.6.1 Primary Part MLP200 with Standard Encapsulation



Motortyp / Type	L±2	C±0.3	N
MLP200A-XXXX-FS-...	360	80	2
MLP200B-XXXX-FS-...	510	55	4
MLP200C-XXXX-FS-...	660	80	5
MLP200D-XXXX-FS-...	810	55	7

Dimensions, Installation Dimension and Tolerances

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

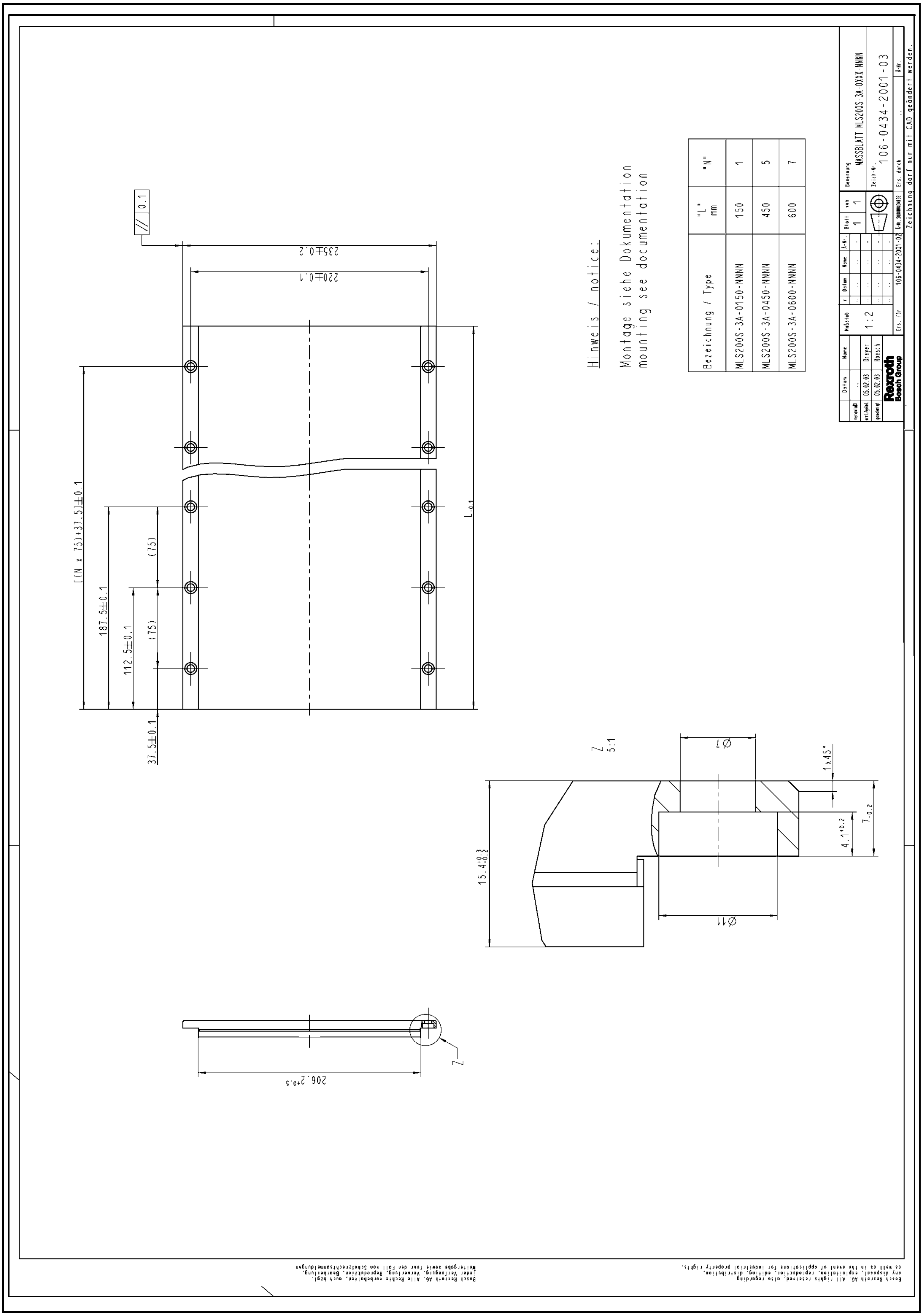
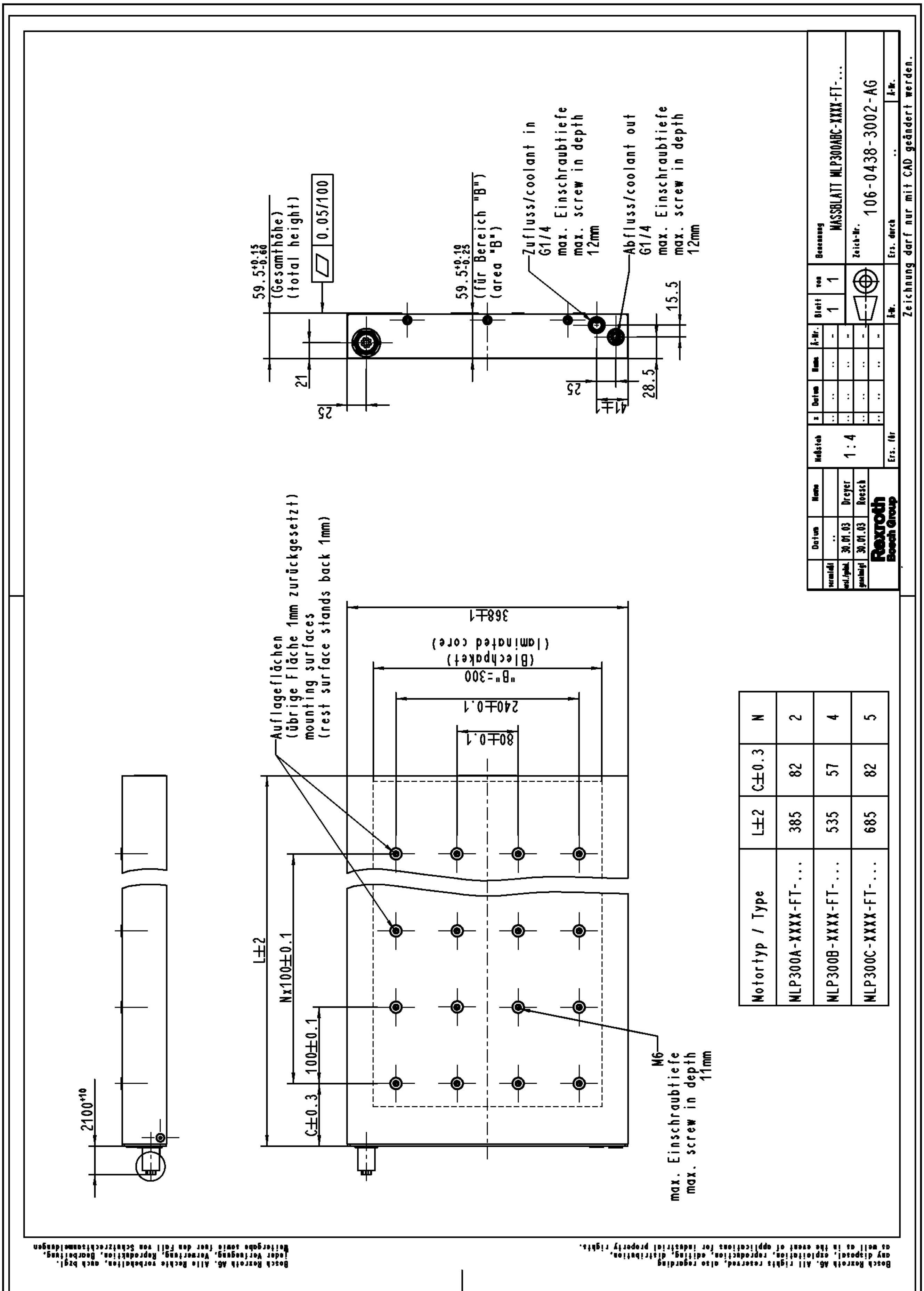


Fig.5-17: Secondary Part MLS200

Dimensions, Installation Dimension and Tolerances

5.7 Dimension Sheets Frame Size 300

5.7.1 Primary Part MLP300 with Thermo Encapsulation



5.7.2 Secondary Part MLS300

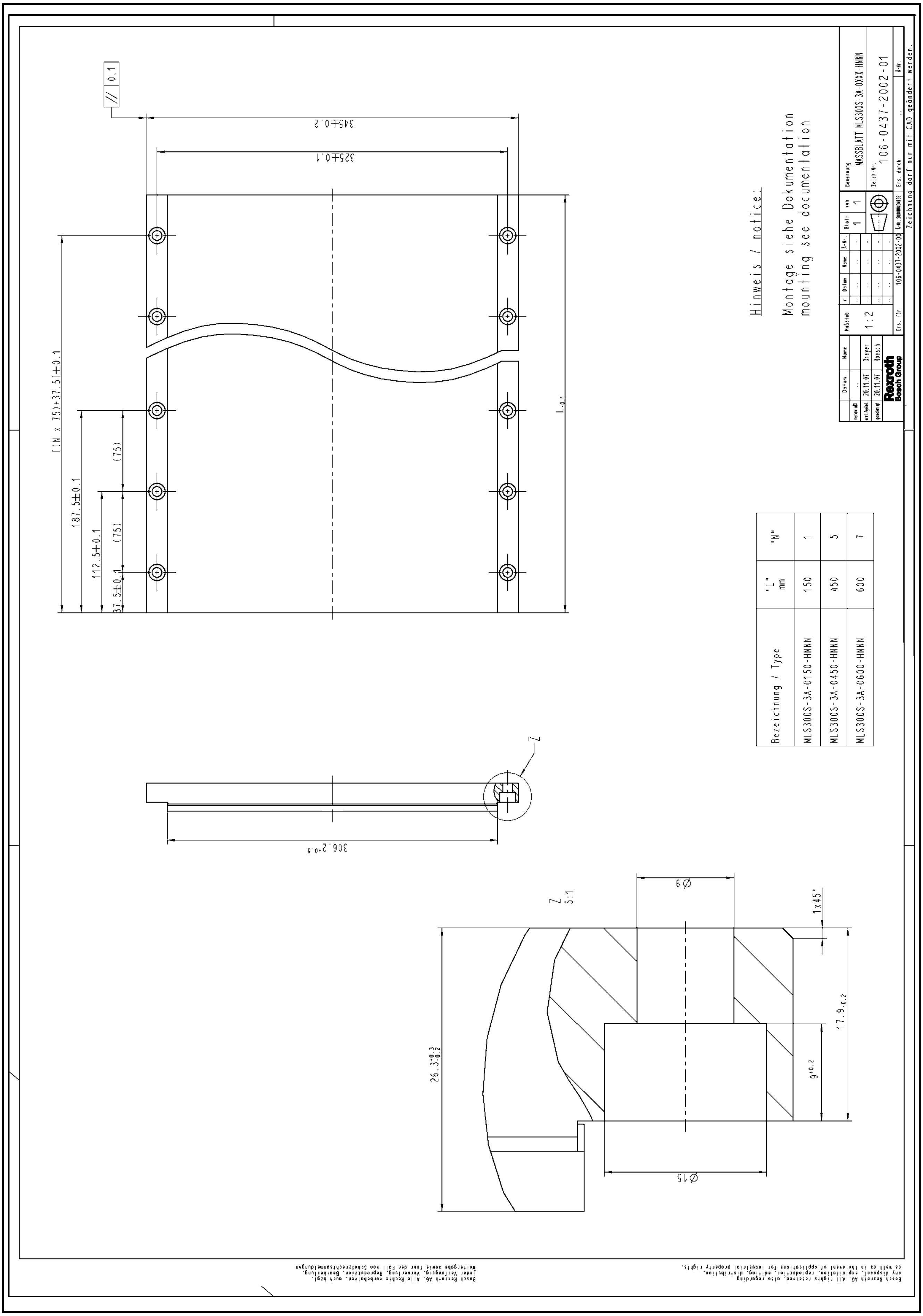


Fig.5-19: Secondary Part MLS300

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.

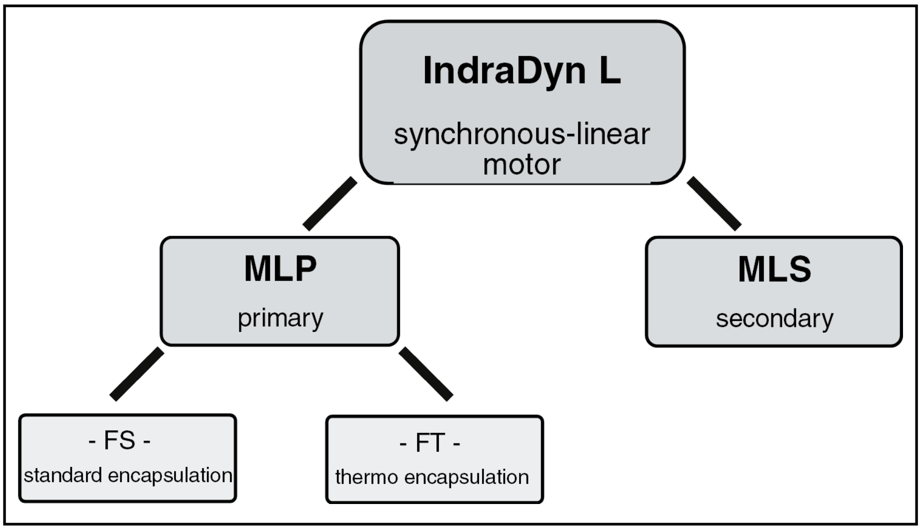


Fig.6-1: Short term for IndraDyn L

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”.

Type Code IndraDyn L

6.1.2 Type Code Primary Part MLP

General Information

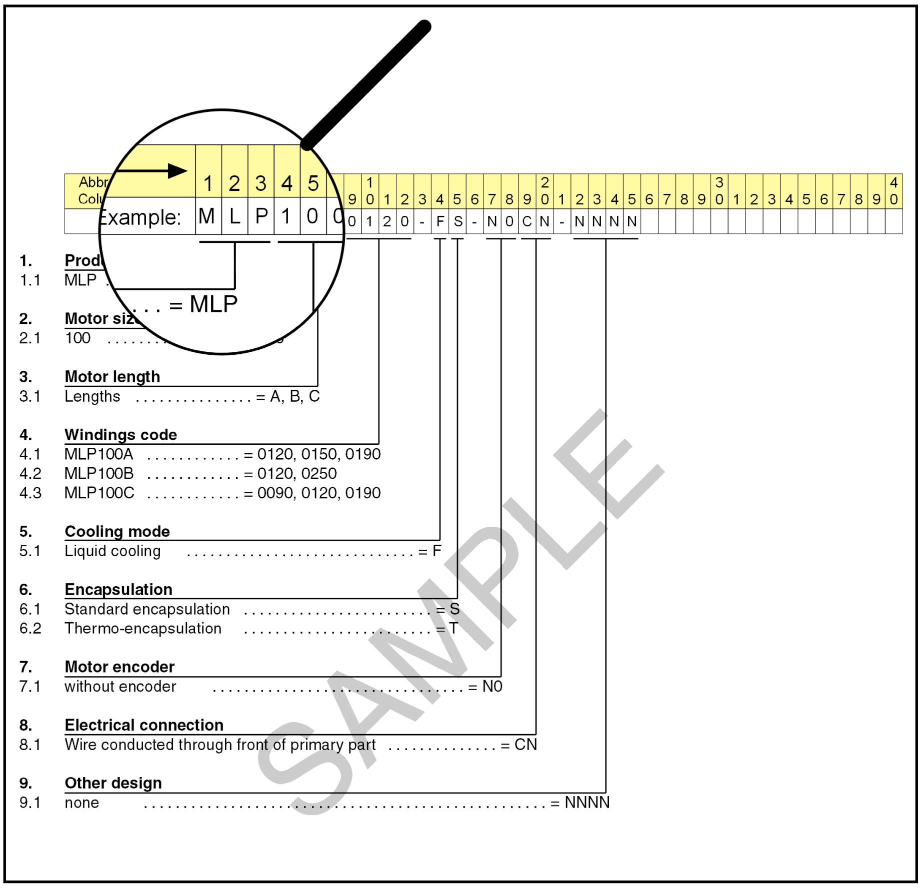


Fig.6-2: Example for a type code primary part MLP100

Component MLP

Short-text columns 123

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

Motor Frame Size

Short-text columns 456

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

Motor Length

Short-text column 7

Within a series, the grading of increasing motor 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

Short-text 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

Short-text 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

Short-text columns 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

Short-text columns 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

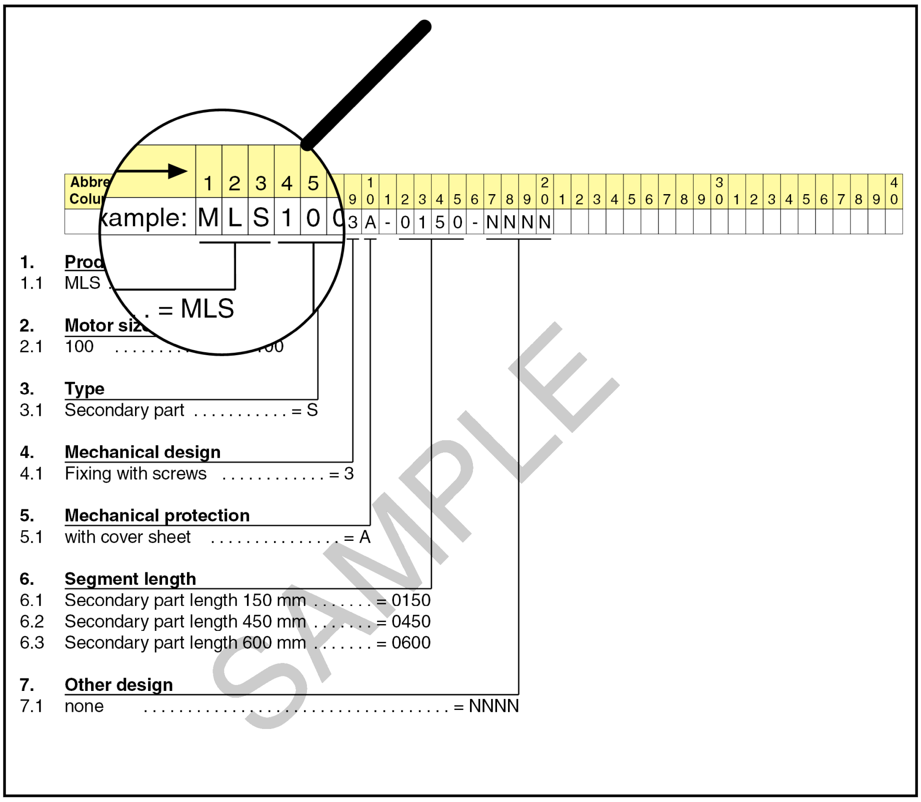


Fig.6-3: Example for a type code secondary part MLS100

Component MLS

Short-text columns 123

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

Type Code IndraDyn L

Motor Frame Size

Short-text columns 456

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

Type

Short-text column 7

S = secondary part

Mechanical Design

Short-text column 9

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

Mechanical Protection

Short-text 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

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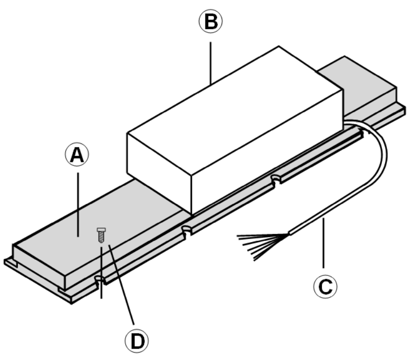
Illustration example: MLP040



Ⓐ 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

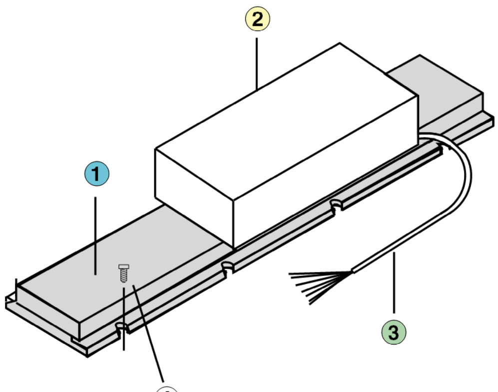
4. Mechanical design
4.1 Fixing with screws . . . . = 3

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	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	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 Frame Size
2.1 070 . . . . = 070

3. Motor Frame Lengths
3.1 Frame lengths. . . . .= A, B, C

4. Winding Designation
4.1 MLP070A = 0150, 0220, 0300
4.2 MLP070B = 0100, 0120, 0150, 0250, 0300
4.3 MLP070C = 0030, 0120, 0150, 0240, 0300

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

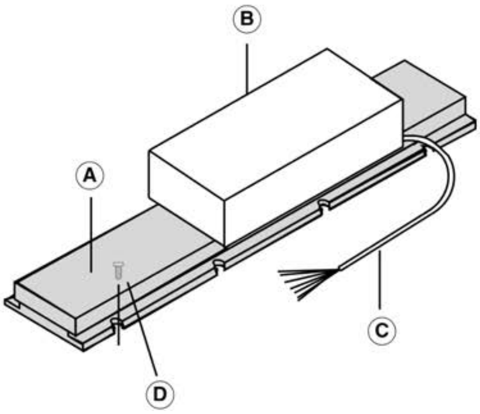
6. Encapsulation
6.1 Standard encapsulation. . . . .= S
6.2 Thermal encapsulation. . . . .= T

7. Motor Encoder
7.1 Without encoder. . . . . = N0

8. Electrical Connection
8.1 Cable lead out from front side of the primary part . . . . = CN

9. Other Design
9.1 None . . . . = NNNN

Example: MLP070



Ⓐ Secondary part MLS
Ⓑ Primary part MLP (depending from design - Standard encapsulation or thermal encapsulation)
Ⓒ Electrical connection
Ⓓ Screw fastening (from top)

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

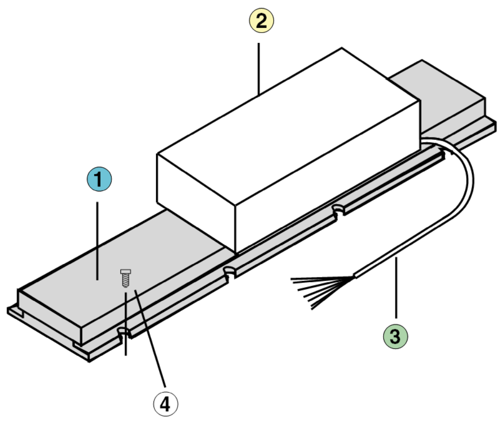
4. Mechanical design
4.1 Fixing with screws . . . . = 3

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	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	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 Frame Size
2.1 100 .... = 100

3. Motor Frame Length
3.1 Frame Lengths............. = A, B, C

4. Winding Designation
4.1 MLP100A .... = 0090, 0120, 0150, 0190
4.2 MLP100B .... = 0030, 0120, 0250
4.3 MLP100C .... = 0090, 0120, 0190

5. Cooling
5.1 Liquid Cooling .... = F

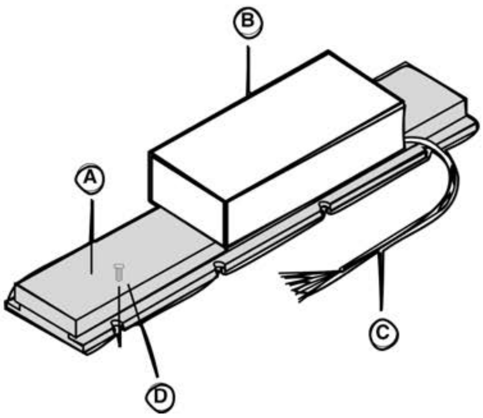
6. Encapsulation
6.1 Standard encapsulation......................... = S
6.2 Thermal encapsulation .... = T

7. Motor Encoder
7.1 Without encoder.................................... = N0

8. Electrical Connection
8.1 Cable lead out on the front side of the primary part .... = CN

9. Other Design
9.1 None.. = NNNN

Example: MLP100



(A) Sekundary part MLS
(B) Primary part MLP (depending from design - standard encapsulation or thermal encapsulation)
(C) Electrical connection
(D) Screw fastening (from top)

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

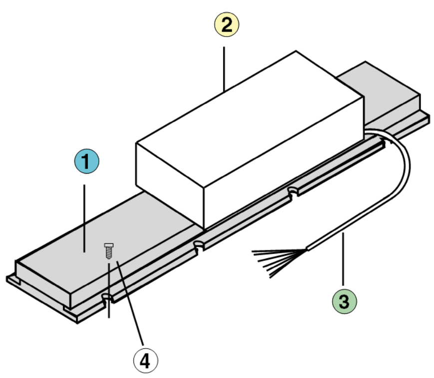
6.2 Secondary part length 450 mm . . . . = 0450

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	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	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

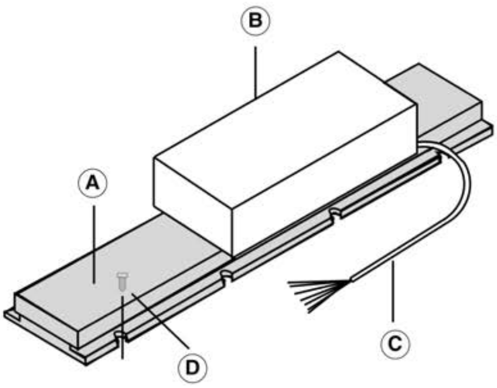
6. Encapsulation
6.1 Standard encapsulation . . . . = S
6.2 Thermo encapsulation . . . . = T

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



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

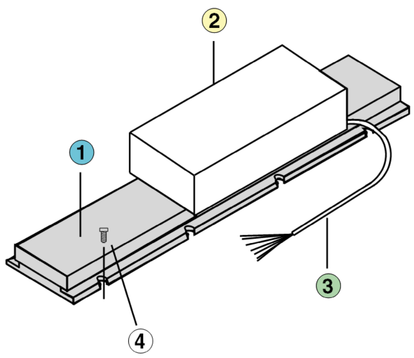
4. Mechanical design
4.1 Fixing with screws . . . . = 3

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
Example:	M	L	P	2	0	0	A	-	0	1	2	0	-	F	S	-	N	0	C	N

Abbrev. Column	1	2	3	4	5	6	7	8	9	30	1	2	3	4	5	6	7	8	9	40
Example:	-	N	N	N	N															

1. Product
1.1 MLP .... = MLP

2. Motor Frame Size
2.1 200 .... = 200

3. Motor Frame Lengths
3.1 Frame Lengths ....= A, B, C, D

4. Winding Designation
4.1 MLP200A .... = 0090, 0120
4.2 MLP200B .... = 0040, 0120
4.3 MLP200C .... = 0090, 0120, 0170
4.4 MLP200D .... = 0035, 0060, 0100, 0120

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

6. Encapsulation
6.1 Standard encapsulation..........................= S
6.2 Thermal encapsulation...........................= T

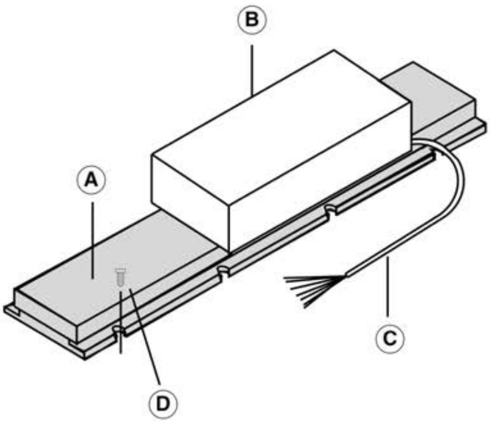
7. Motor Encoder
7.1 Without encoder.................................... = N0

8. Electrical Connection
8.1 Cable lead out from front side of primary part .... = CN

9. Other Design
9.1 None .... = NNNN

ZN-40017-200_NOR_N_DE_2011-12-22

Example: MLP200



Ⓐ Secondary part MLS
Ⓑ Primary part MLP (depending from design - standard encapsulation or thermal encapsulation)
Ⓒ Electrical connection
Ⓓ Screw fastening (from top)

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

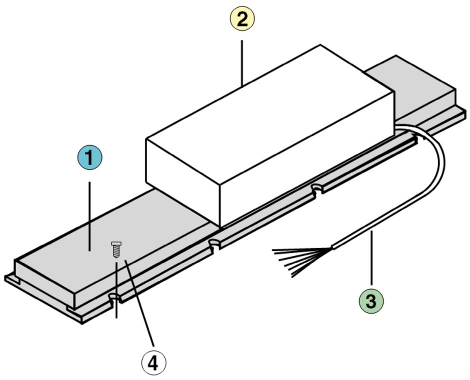
4. Mechanical design
4.1 Fixing with screws . . . . = 3

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	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	3	0	0	B	-	0	1	2	0	-	F	T	-	N	0	C	N	-	N	N	N	N															

Product
MLP . . . . = MLP

Motor size
300 . . . . = 300

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

Windings code
MLP300A . . . . = 0090, 0120
MLP300B . . . . = 0070, 0120
MLP300C . . . . = 0060, 0090, 0120

Cooling
Liquid cooling . . . . = F

Encapsulation
Thermo-encapsulation . . . . = T

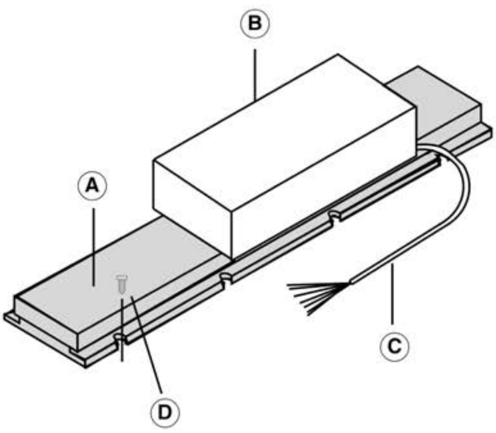
Encoder
without encoder . . . . = N0

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

Other design
none . . . . = NNNN

ZN-40017-300_NOR_N_EN_2012-08-10

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

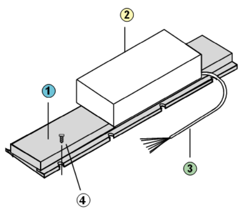
Mechanical design
Fixing per screws . . . . = 3

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 Ecodrive 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.

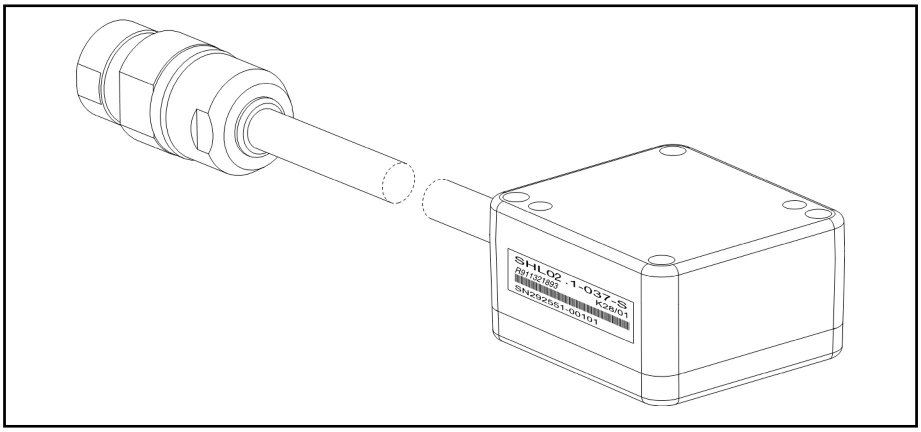
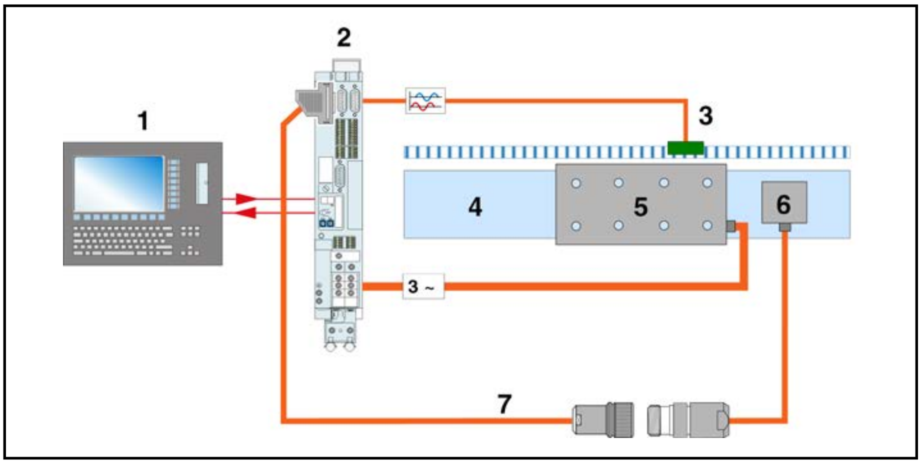


Fig.7-1: Accessory Hall sensor box SHL

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 Connection Cable on Primary Part

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

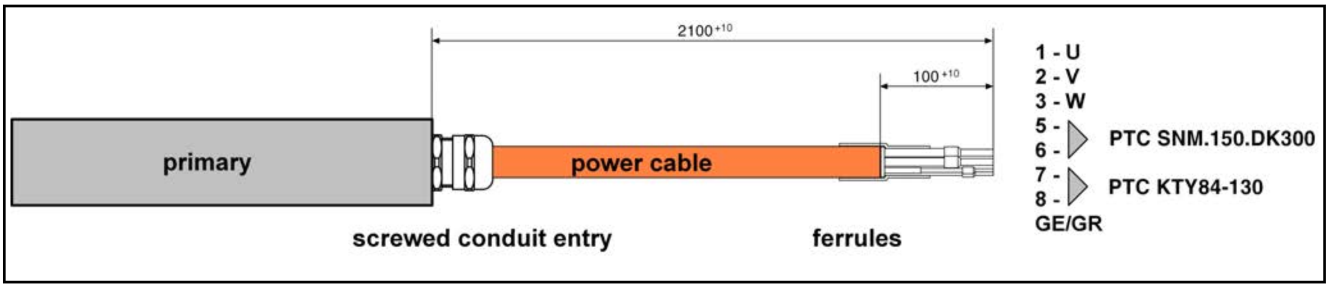


Fig.8-1: Design of connection cable on the primary part MLP

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

Motor frame size	Connection cable	Cross section Power wires	Cross section Control wire	Diameter (D)	Bending radius statically
MLP040x-xxxx	INK0653	1.0 mm^2	0.75 mm^2	12 mm	5 x D
MLP070x-xxxx	INK0603	4.0 mm^2	1,0 or 1.5 mm^2	16.3 mm	
MLP100x-xxxx MLP140A-xxxx MLP140B-xxxx MLP140C-0050 MLP140C-0120 MLP140C-0170 MLP200A-xxxx MLP200B-xxxx MLP200C-0090 MLP200D-0060	INK0604	6.0 mm^2		18.5 mm	
MLP140C-0350 MLP200C-0120 MLP200C-0170 MLP200D-0100 MLP200D-0120 MLP300x-xxxx	INK0605	10.0 mm^2		22.2 mm	

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

Connection cable installation

The connection cable, which is connected to the primary part, ends with open wire end, provided with wire end ferrules (see Fig. 8-1) 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 installation to

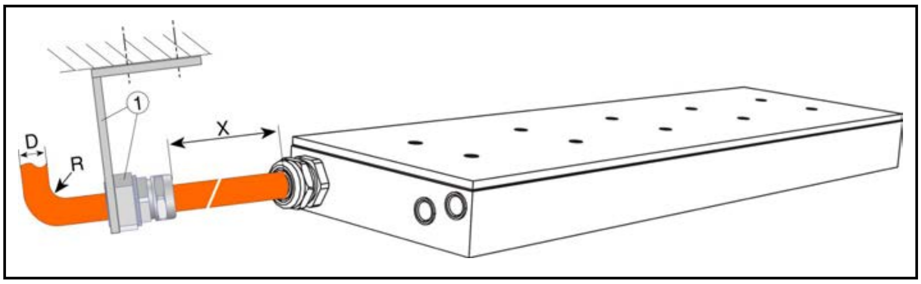
- a flange socket,
- a coupling or
- a terminal box (not in the scope of delivery of Rexroth)

. From this junction, the power supply with the connection cable can be laid through a drag chain, resp. the machine construction. Also refer toChapter 8-9 on page 118. Appropriate ready-made power cables are available from Rexroth.

NOTICE

Avoid bending, pulling and pushing loads as well as continuous movements of the connection cable at the point where the cable exits from the primary part. Any load of this kind, can lead to irreparable damage (e.g. cable break) on the primary part!

No passing of the connection cables in a drag chain. If a fixed installation is not possible, provide the connection cable with a strain relief (see Fig. 8-3) to protect the cable and the primary part from any damage (e.g. cable break).



Dimension "x"	Minimum distance 10 mm
①	Strain relief of the connection cable on MLP primary part
D	Diameter connection cable - see Fig. 8-2 on page 113
R	Diameter connection cable - see Fig. 8-2 on page 113

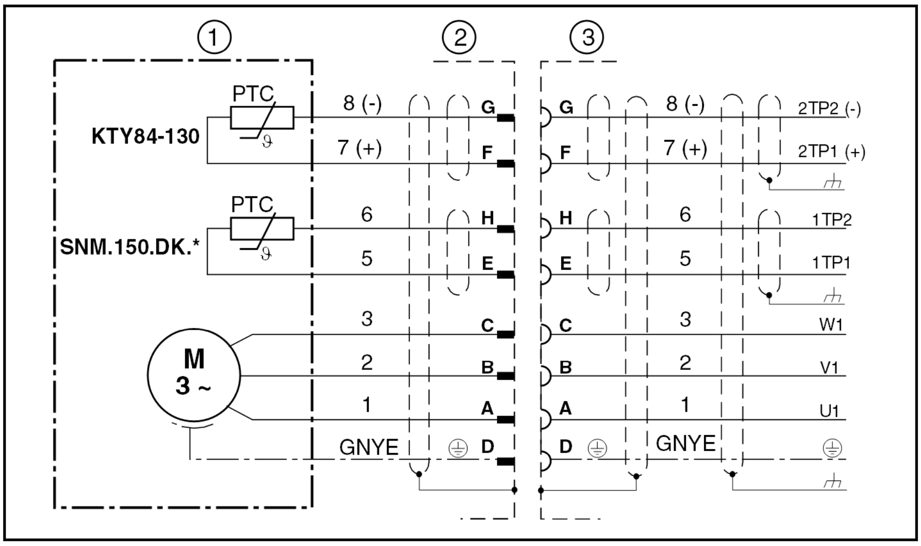
Fig.8-3: Example for strain relief of connection cable

☞ The connection cable is 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

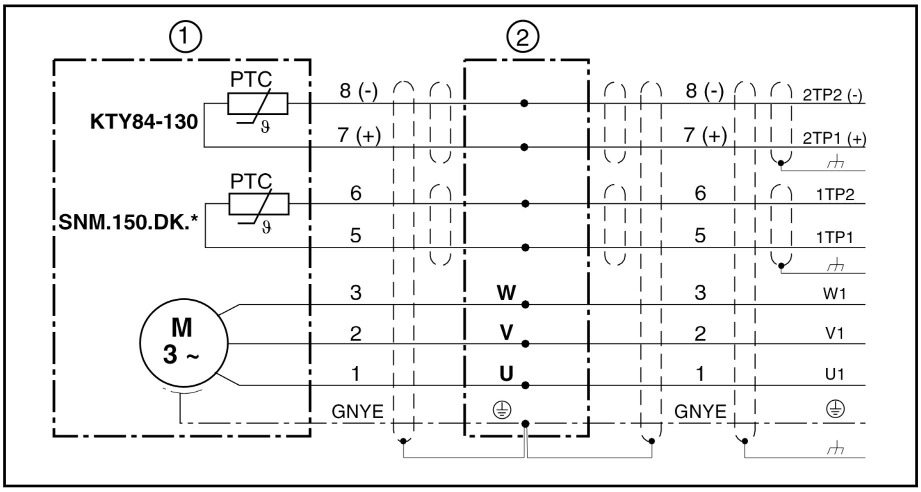
Connection via Flange Socket and Coupling



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

Electrical Connection

Connection for single arrangement

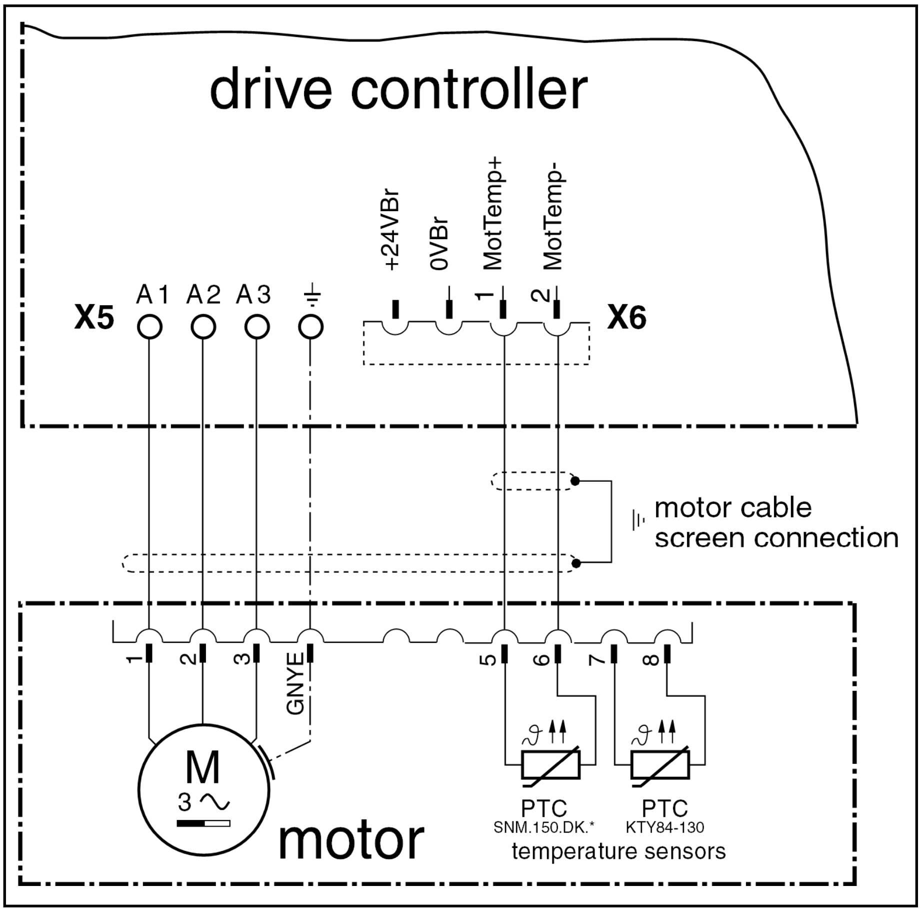


Fig.8-6: *Connection on the drive-controller – separate arrangement primary part*

Connection for parallel arrangement

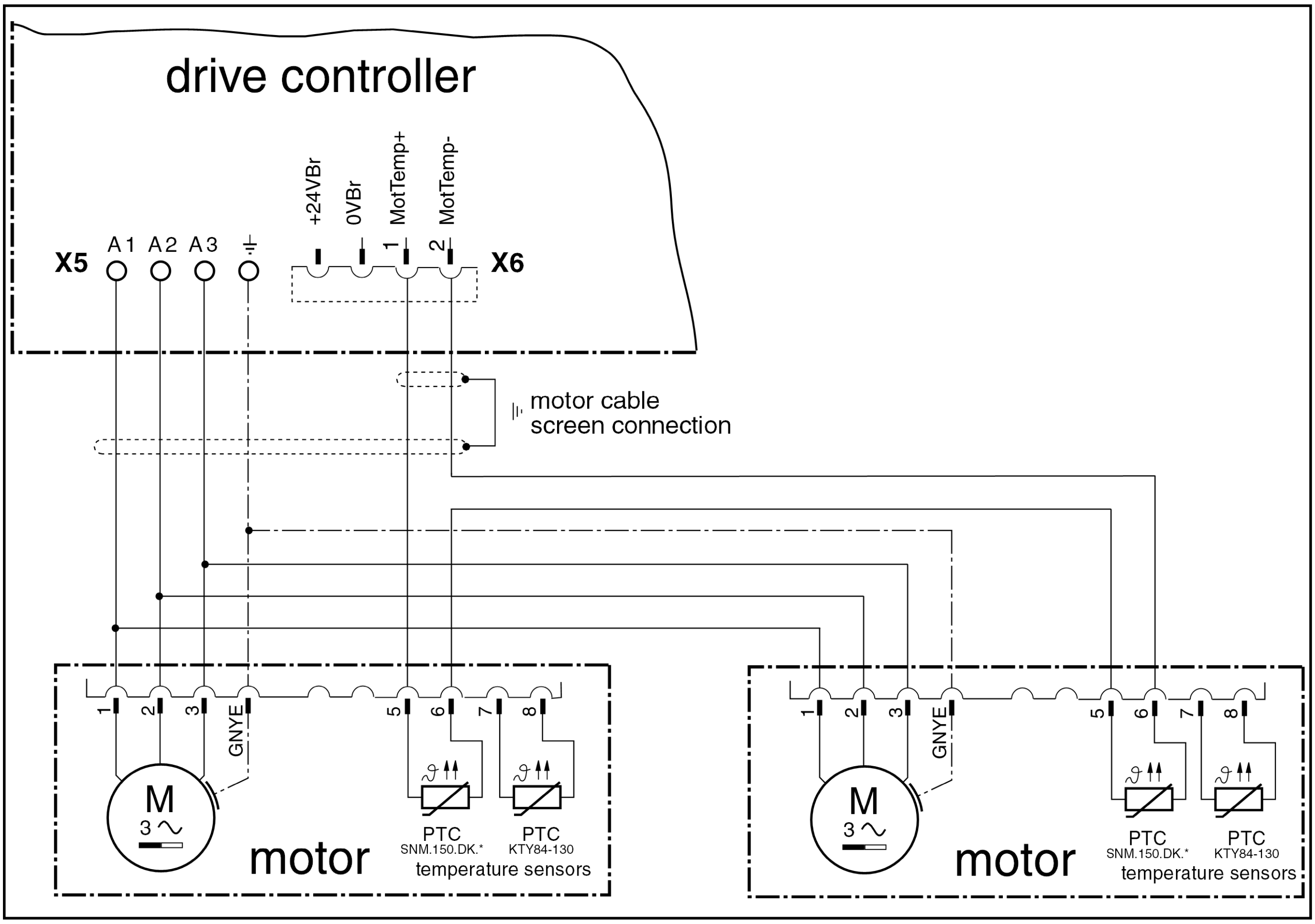


Fig.8-7: Connection on the drive-controller – parallel arrangement primary part

Connection Power Cable for Primary Part at Parallel Arrangement

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

Connection at arrangement acc. to Fig. 9-16 on page 135 (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 and Fig. 9-23 on page 136 (cable outlet in the opposite direction)			
Drive-controller X5	A1	A2	A3
Primary part 1	A1	A2	A3
Primary part 2	A1	**A3**	**A2**

Fig.8-8: Connection of the power wires in case of parallel arrangement of primary parts on a drive controller

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 power cable.

- Installation of a collective power cable with higher cross-section (Fig. 8-11 on page 119)
- Installation of two separate parallel power cables (Fig. 8-10 on page 118)

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

Power connection at separate arrangement

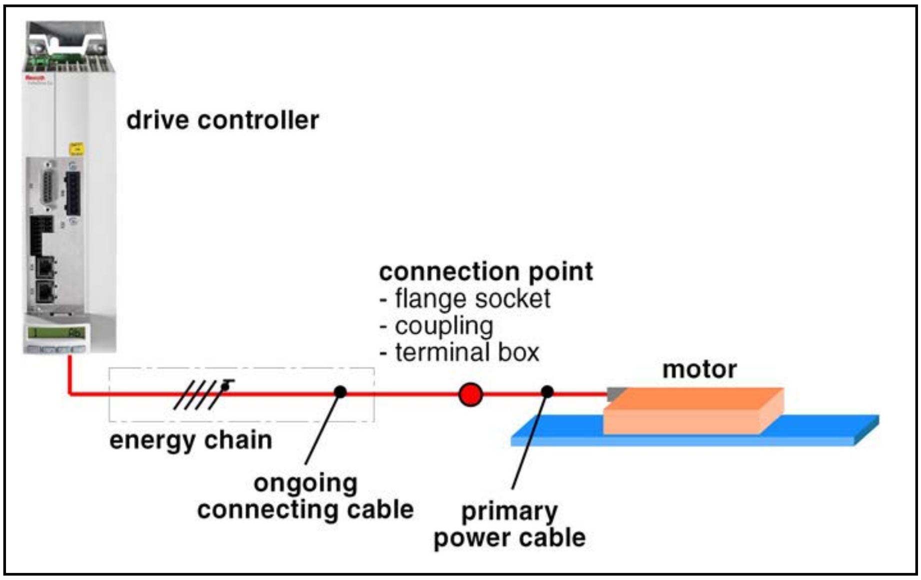


Fig.8-9: Power connection at separate arrangement

Power connection at parallel arrangement, separate connection cable

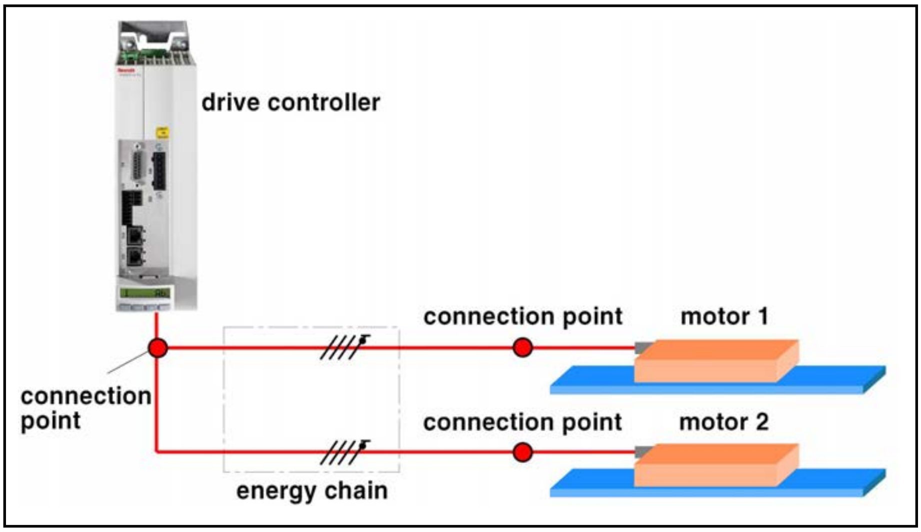


Fig.8-10: Parallel arrangement, separate power cables

Power connection at parallel arrangement, collective connection cable with higher crosssection

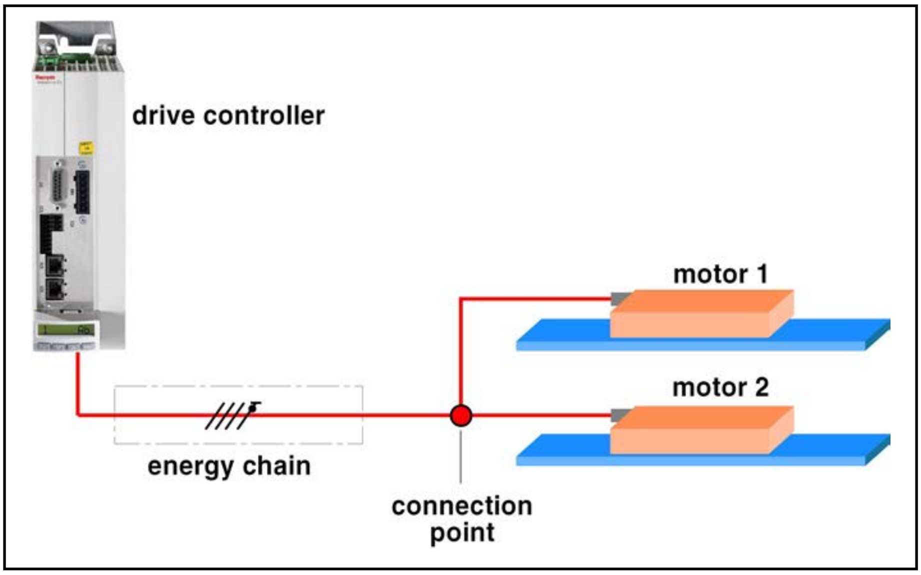


Fig.8-11: Parallel arrangement, collective power cable

Selecting Power 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...	Rated current of the motor in A (Effective value)	Connection cable at single or parallel arrangement with separate power cables	Power cable at parallel arrangement with collective power cable
040A-0300	see chapter 4 "Technical Data IndraDyn L" on page 27	1.0 mm² (INK653)	1.0 mm² (INK653)
040B-0150			
040B-0250			
040B-0350			

Electrical Connection

<table>
<tr><th>Primary part MLP...</th><th>Rated current of the motor in A
(Effective value)</th><th>Connection cable at single or parallel arrangement with separate power cables</th><th>Power cable at parallel arrangement with collective power cable</th></tr>
<tr><td>070A-0150</td><td rowspan="31">see chapter 4 "Technical Data IndraDyn L" on page 27</td><td rowspan="12">1.0 mm^2 (INK653)</td><td rowspan="2">1.0 mm^2 (INK653)</td></tr>
<tr><td>070A-0220</td></tr>
<tr><td>070A-0300</td><td>2.5 mm^2 (INK602)</td></tr>
<tr><td>070B-0100</td><td rowspan="3">1.0 mm^2 (INK653)</td></tr>
<tr><td>070B-0120</td></tr>
<tr><td>070B-0150</td></tr>
<tr><td>070B-0250</td><td>2.5 mm^2 (INK602)</td></tr>
<tr><td>070B-0300</td><td>4 mm^2 (INK603)</td></tr>
<tr><td>070C-0030</td><td>1.0 mm^2 (INK653)</td></tr>
<tr><td>070C-0120</td><td rowspan="2">2.5 mm^2 (INK602)</td></tr>
<tr><td>070C-0150</td></tr>
<tr><td>070C-0240</td><td>4 mm^2 (INK603)</td></tr>
<tr><td>070C-0300</td><td>2.5 mm^2 (INK602)</td><td>6 mm^2 (INK604)</td></tr>
<tr><td>100A-0090</td><td rowspan="6">1.0 mm^2 (INK653)</td><td>1.5 mm^2 (INK650)</td></tr>
<tr><td>100A-0120</td><td rowspan="2">2.5 mm^2 (INK602)</td></tr>
<tr><td>100A-0150</td></tr>
<tr><td>100A-0190</td><td rowspan="3">4 mm^2 (INK603)</td></tr>
<tr><td>100B-0030</td></tr>
<tr><td>100B-0120</td></tr>
<tr><td>100B-0250</td><td>2.5 mm^2 (INK602)</td><td>10 mm^2 (INK605)</td></tr>
<tr><td>100C-0090</td><td>1.0 mm^2 (INK653)</td><td>4 mm^2 (INK603)</td></tr>
<tr><td>100C-0120</td><td>1.5 mm^2 (INK650)</td><td>6 mm^2 (INK604)</td></tr>
<tr><td>100C-0190</td><td>4 mm^2 (INK603)</td><td>10 mm^2 (INK605)</td></tr>
<tr><td>140A-0030</td><td>1.0 mm^2 (INK653)</td><td>1.0 mm^2 (INK653)</td></tr>
<tr><td>140A-0120</td><td>1.0 mm^2 (INK653)</td><td>4 mm^2 (INK603)</td></tr>
<tr><td>140B-0090</td><td>1.5 mm^2 (INK650)</td><td rowspan="2">6 mm^2 (INK604)</td></tr>
<tr><td>140B-0120</td><td>2.5 mm^2 (INK602)</td></tr>
<tr><td>140C-0050</td><td>1.0 mm^2 (INK653)</td><td>4 mm^2 (INK603)</td></tr>
<tr><td>140C-0120</td><td>2.5 mm^2 (INK602)</td><td>10 mm^2 (INK605)</td></tr>
<tr><td>140C-0170</td><td>4 mm^2 (INK603)</td><td>16 mm^2 (INK606)</td></tr>
<tr><td>140C-0350</td><td>10 mm^2 (INK605)</td><td>----</td></tr>
</table>

<table>
<tr><th>Primary part MLP...</th><th>Rated current of the motor in A

(Effective value)</th><th>Connection cable at single or parallel arrangement with separate power cables</th><th>Power cable at parallel arrangement with collective power cable</th></tr>
<tr><td>200A-0090</td><td rowspan="18">see chapter 4 "Technical Data IndraDyn L" on page 27</td><td>1.0 mm² (INK653)</td><td>4 mm² (INK603)</td></tr>
<tr><td>200A-0120</td><td>2.5 mm² (INK602)</td><td>6 mm² (INK604)</td></tr>
<tr><td>200B-0040</td><td>1.0 mm² (INK653)</td><td>4 mm² (INK603)</td></tr>
<tr><td>200B-0120</td><td>2.5 mm² (INK602)</td><td rowspan="2">10 mm² (INK605)</td></tr>
<tr><td>200C-0090</td><td>4 mm² (INK603)</td></tr>
<tr><td>200C-0120</td><td>6 mm² (INK604)</td><td>16 mm² (INK606)</td></tr>
<tr><td>200C-0170</td><td>10 mm² (INK605)</td><td>25 mm² (INK607)</td></tr>
<tr><td>200D-0035</td><td>2.5 mm² (INK602)</td><td>10 mm² (INK605)</td></tr>
<tr><td>200D-0060</td><td>4 mm² (INK603)</td><td>10 mm² (INK605)</td></tr>
<tr><td>200D-0100</td><td rowspan="2">10 mm² (INK605)</td><td>25 mm² (INK607)</td></tr>
<tr><td>200D-0120</td><td>-----</td></tr>
<tr><td>300A-0090</td><td>2.5 mm² (INK602)</td><td>6 mm² (INK604)</td></tr>
<tr><td>300A-0120</td><td rowspan="2">4 mm² (INK603)</td><td>10 mm² (INK605)</td></tr>
<tr><td>300B-0070</td><td rowspan="3">16 mm² (INK606)</td></tr>
<tr><td>300B-0120</td><td>6 mm² (INK604)</td></tr>
<tr><td>300C-0060</td><td>4 mm² (INK603)</td></tr>
<tr><td>300C-0090</td><td>6 mm² (INK604)</td><td rowspan="2">25 mm² (INK607)</td></tr>
<tr><td>300C-0120</td><td>10 mm² (INK605)</td></tr>
</table>

Fig.8-12: Necessary cross-section of the power wires depend on the motor type, arrangement and connection type

Additional description of the power cables is done in the documentation "Rexroth Connection Cables", MNR R911322948 (DE) or R911322949 (EN).

8.2 Sensors

8.2.1 Temperature Sensors

To ensure safe motor protection Schutz der Wicklungagainst thermal overload, temperature sensor SNM150.DK must be connected to the drive controller. Temperature sensor KTY84-130 can be used for external temperature measurements. Observe the respective connection diagram for the selected connection type (flange socket or terminal box) when connecting the temperature sensors. For more information about the temperature sensors, please refer to chapter 9.7 "Motor Temperature Monitoring" on page 161.

- KTY84-130 is an ESD sensitive device! For this reason, the wires of the sensor are protected by a protective foil at the connection cable. Before connecting the sensor, take appropriate measures for ESD protection (ESD = electrostatic discharge).
- The used temperature sensors are double or reinforced insulated according to DIN EN 50178, so separation exists according to DIN EN 61800-5-1.

8.2.2 Connection of Length Measurement System

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

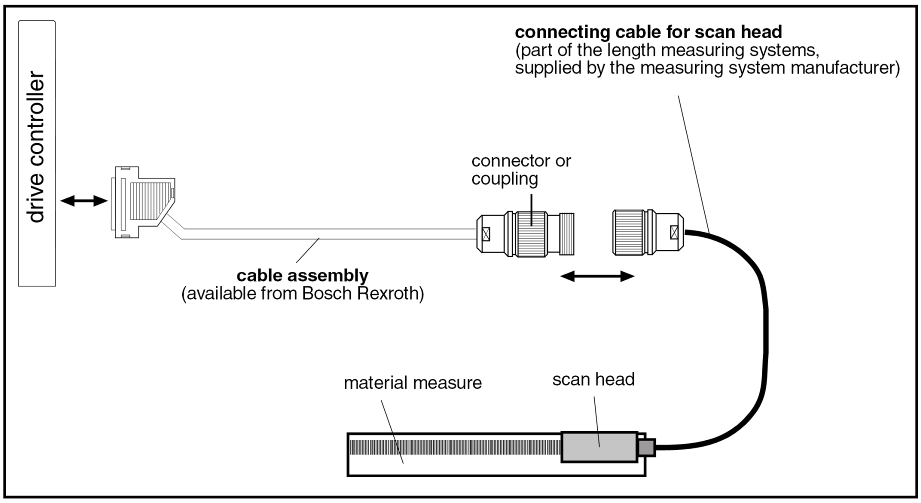


Fig.8-13: Connection example length measurement system

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	Voltage	Voltage
Signal flow line	Sinus	Sinus
Signal amplitude	1 VSS	1 VSS
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 DKCxx.3 <--> Flange socket IndraDrive <--> Flange socket	IKS 4142 IKS 4001 IKS 4038	IKS 4384 IKS 4002 IKS 4041
DIAX04 <--> Coupling DKCxx.3 <--> Coupling IndraDrive <--> Coupling	--- --- ---	IKS 4383 IKS 4389 IKS 4040

Fig.8-14: Connection components length measurement system

9 Application and Construction Instructions

9.1 Functional Principle

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

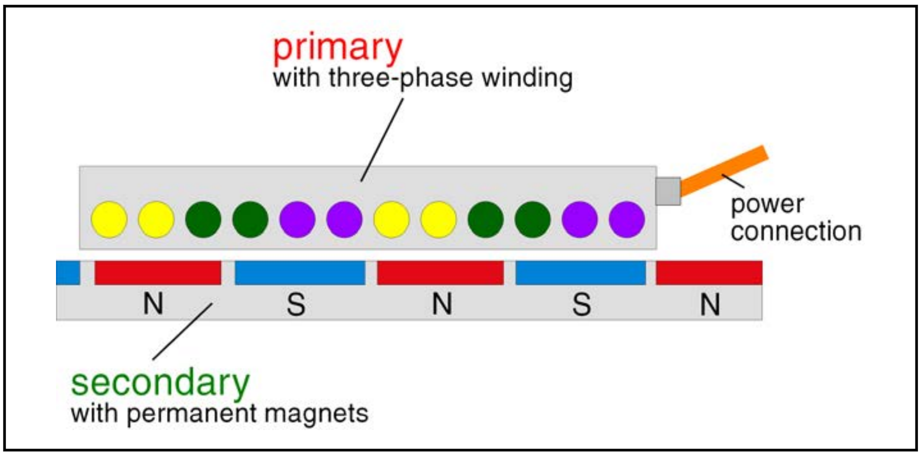


Fig.9-1: General construction of an IndraDyn L motor

The force generation of the IndraDyn L motor, a synchronous-linear motor, is the same as the torque generation at rotary 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 via 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

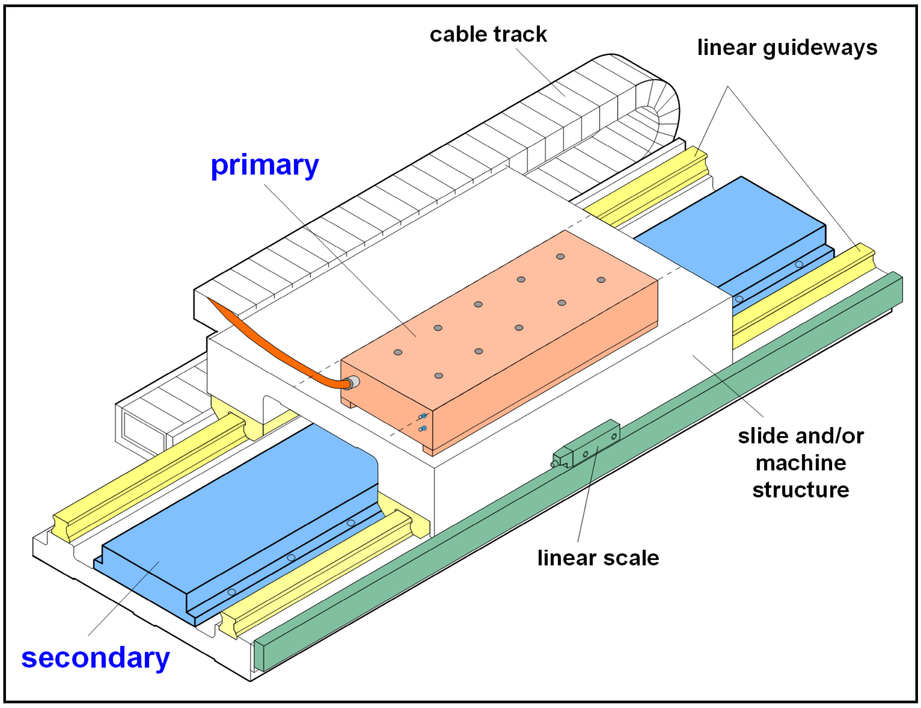


Fig.9-2: General construction of an axis with an IndraDyn L

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 133.

☞ 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 14.1 "Recommended Suppliers of Additional Components " on page 261.

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.

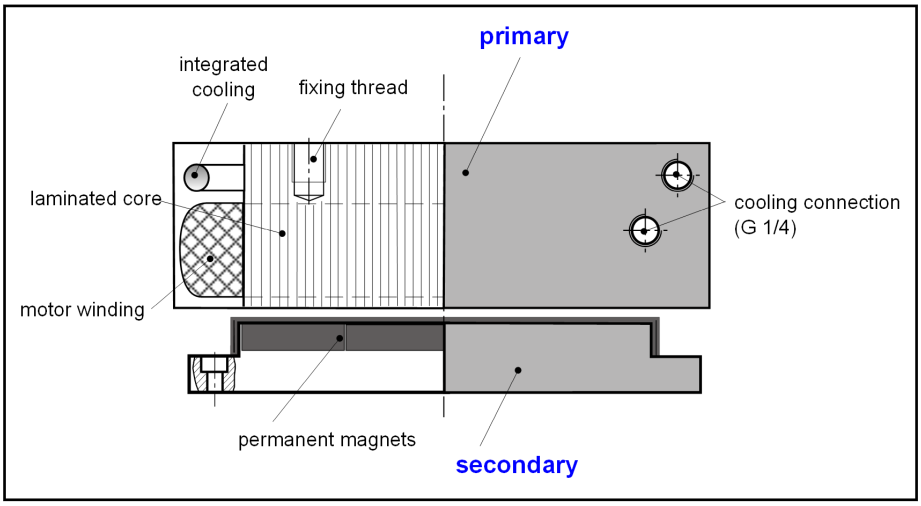


Fig.9-3: Primary part with standard encapsulation

For further notes regarding liquid cooling refer to chapter 9.6 "Motor Cooling" on page 143.

Main application area

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

- General automation
- Handling

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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.

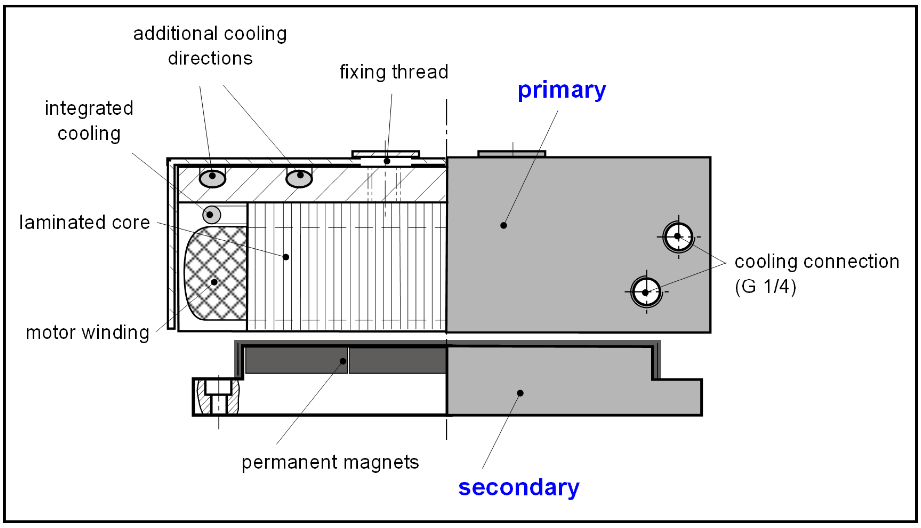

Fig.9-4: Primary part with thermo encapsulation

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" on page 143.

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 9.21 "Wipers" on page 176).

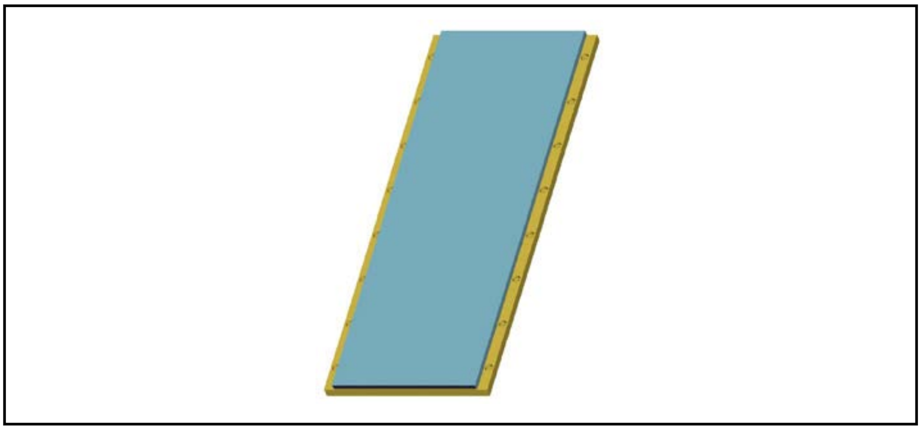

Fig.9-5: Secondary part MLS

☞ 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 95).

- 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:

$$L_{Secondary\ part} \geq L_{Traversepath} + L_{Primary\ part}$$

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:

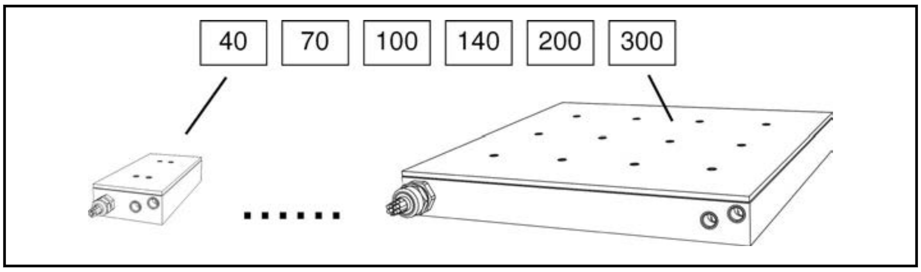

Fig.9-7: Sizes of IndraDyn L synchronous linear motors

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.

Application and Construction Instructions

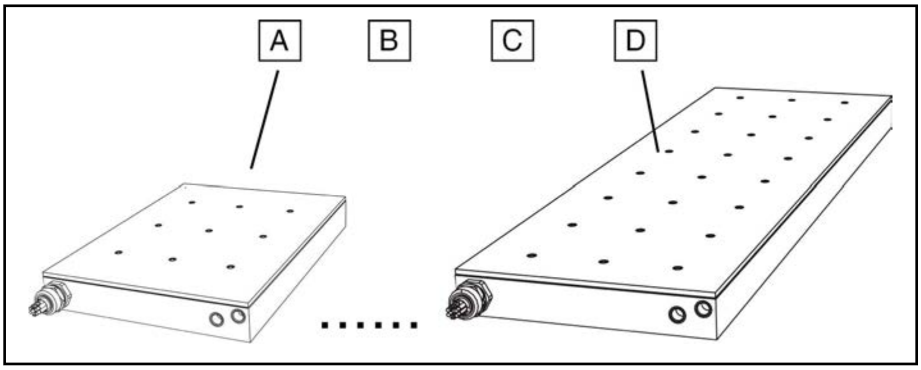

Fig.9-8: Different lengths of primary parts

For detailed information regarding frame sizes and lengths refer to chapter 5 "Dimensions, Installation Dimension and Tolerances" on page 75.

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, as the mass increases. $f \approx \sqrt{1/m}$ auftritt.

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.

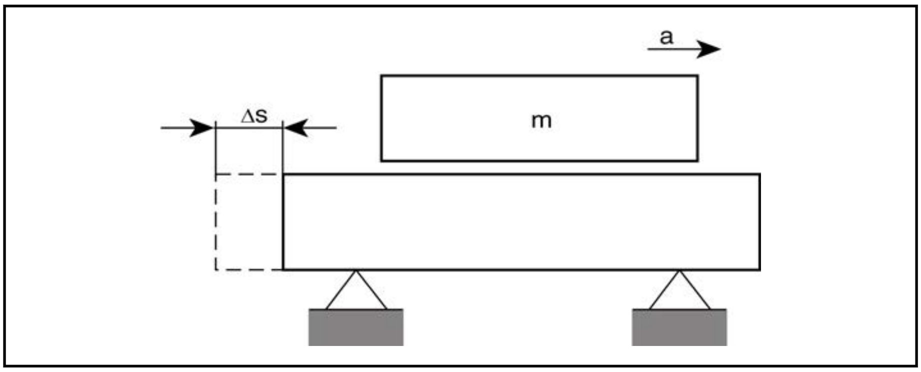

Fig.9-9: Deformation of the machine base caused by the reactive force during the acceleration process

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

Δs	Deformation of displacement of the machine base in µm
m	Mass in kg
l	Acceleration in m/s²
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 9.16 "Length Measuring System " on page 169.

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.

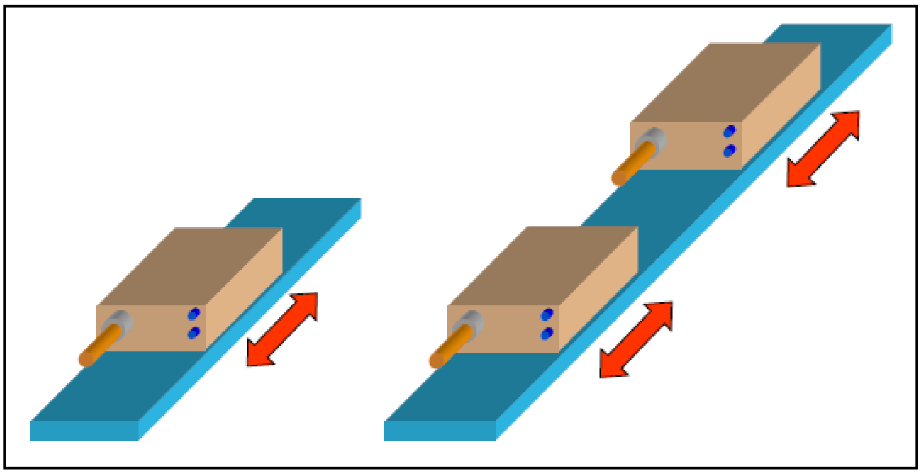

Fig.9-11: Single arrangement of primary parts

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.

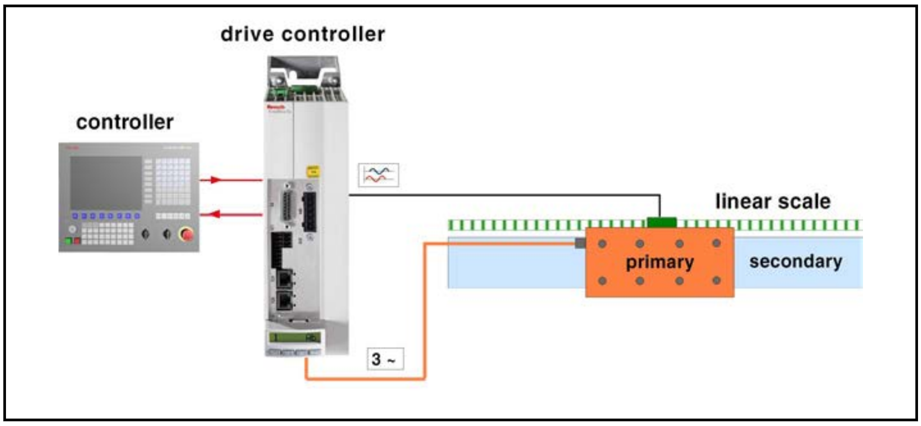

Fig.9-12: Controlling a linear motor with single arrangement of the motor components

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"

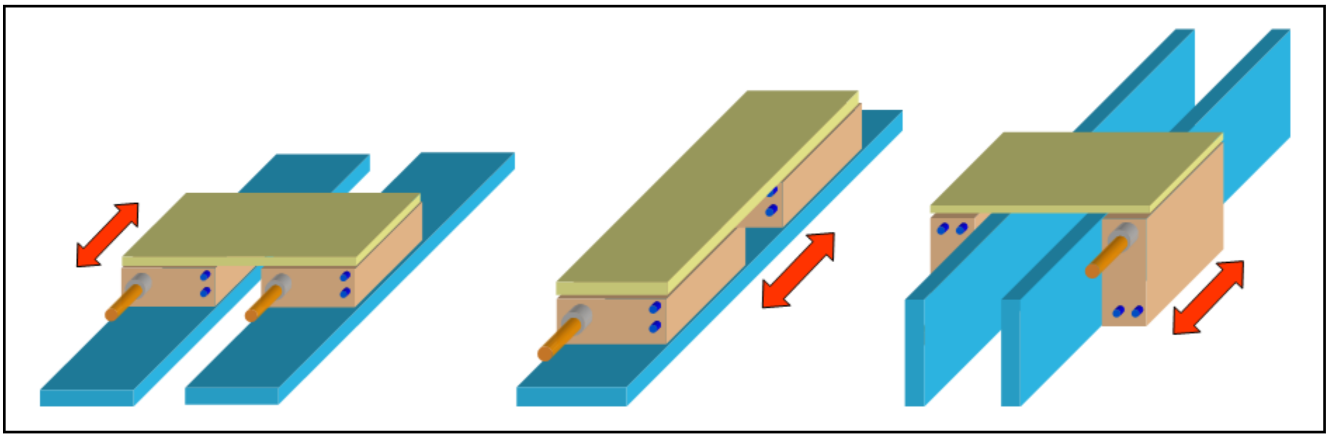

Fig.9-13: Arrangement of several motors per axis

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.

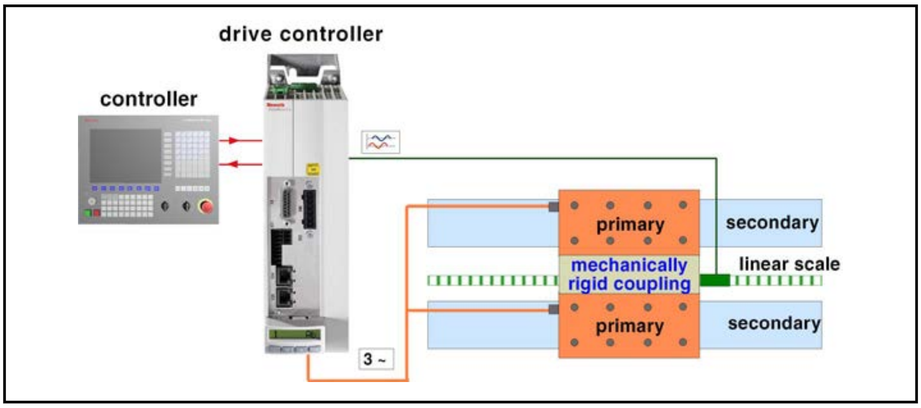

Fig.9-14: Parallel arrangement of two primary parts on one drive controller in conjunction with a length measuring system

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

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- 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

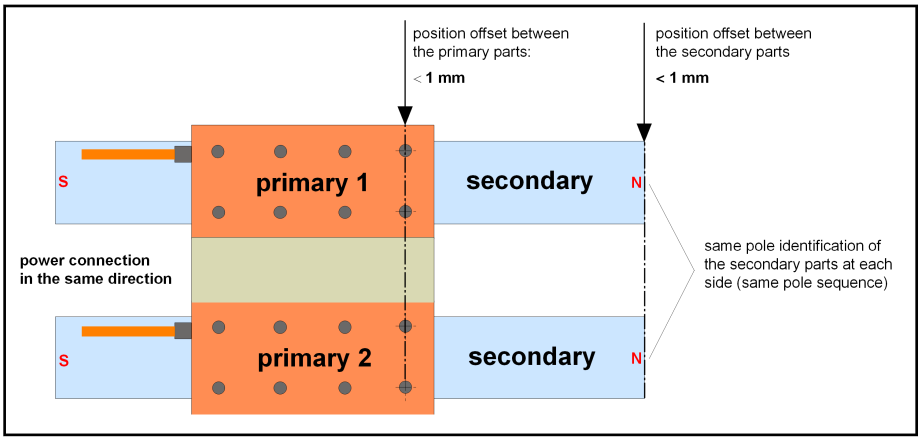

Fig.9-15: Alignment of motor components in parallel arrangement

☞ 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). An offset of the hole grid between the primary parts is only permitted in the structures shown in Fig. 9-17 or Fig. 9-18.

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 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, 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, an integer multiple of twice the electrical pole pitch must be adhered to:

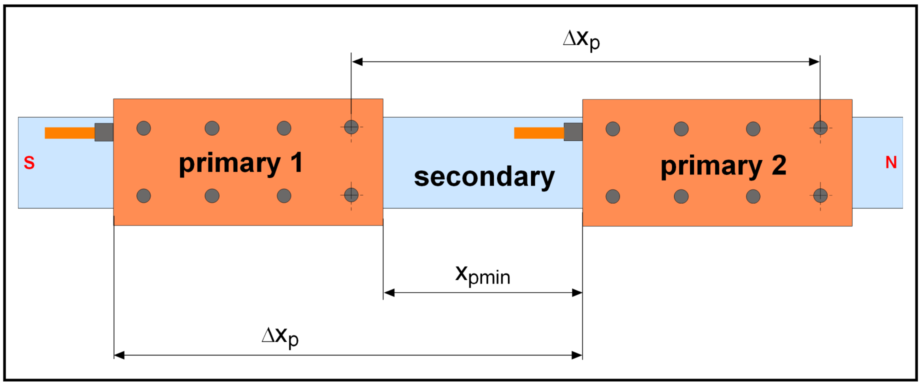

Fig.9-16: Arrangement of the primary parts behind each other and cable entry in the same direction

☞ When you determine the correct primary part distance with cable entries in the same direction acc. to Fig. 9-16, you must always use the same reference point for both primary parts (e.g. the same fastening hole).

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

Δx_P Required grid spacing between the primary parts in mm

τ_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 and Fig. 9-17 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 encapsulationframe 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.

τ_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

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

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, a defined distance must be kept between the primary parts according to Fig. 9-21 and Fig. 9-22.

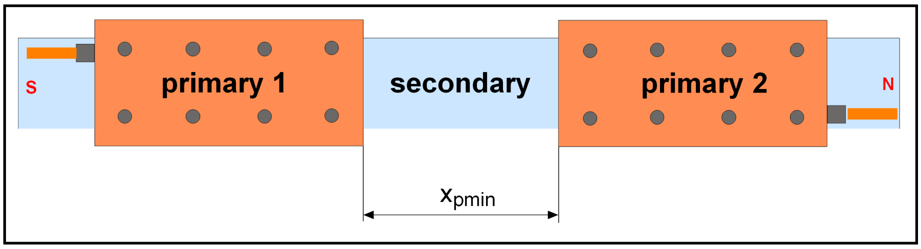

Fig.9-20: Option 1: Arrangement of primary parts behind each other with cable entries in opposite directions

☞ When you determine the correct primary part distance with cable entries in opposite directions according to Fig.9-20 and Fig. 9-23, 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

τ_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 Frame sizes (all)	65
Thermal encapsulation 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 behind each other and with cable entries in opposite directions to Fig. 9-23, a defined distance must be kept between the primary parts according to Fig. 9-24 and Fig. 9-25

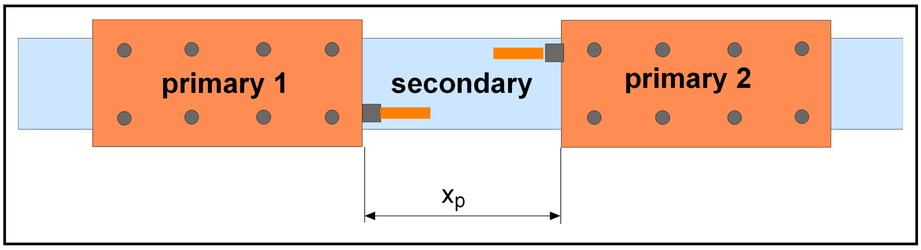

Fig.9-23: Option 2: Arrangement of primary parts behind each other with cable entries in opposite directions

☞ When you determine the correct primary part distance with cable entries in opposite directions according to Fig.9-20 and Fig. 9-23, 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
τ_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 Frame sizes (all)	$40mm + n \cdot 2 \cdot \tau_p$
Thermal encapsulation 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.
τ_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 in case of arrangement with cable outlet in the same direction (see Fig. 9-16)			
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 and Fig. 9-23)			
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 in case of parallel arrangement of primary parts on a drive controller

☞ The primary part 1 according to and 9-20 and Fig. 9-23 is always the reference motor that is used for determining the sensor polarity and for commutation setting (refer also to chapter 13 "Commissioning, Operation and Maintenance" on page 241). Ensure that the secondary part is correctly aligned.

You will find further information about electrical connection in chapter 8 "Electrical Connection" on page 113.

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.

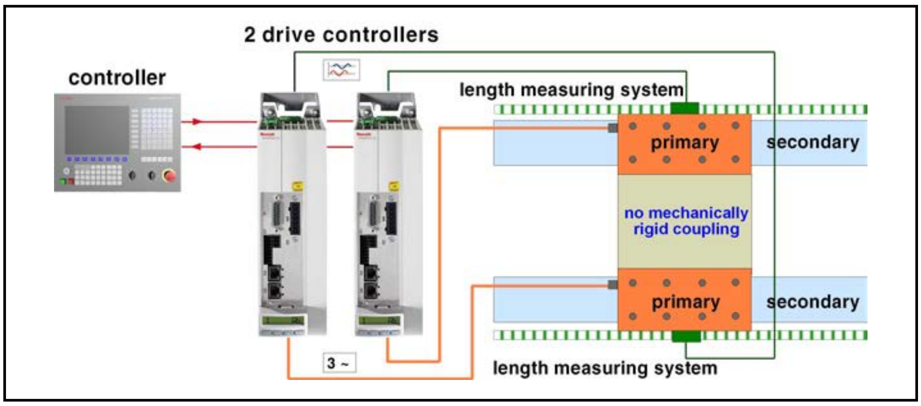

Fig.9-28: Gantry arrangement

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 9.18 "Braking Systems and Holding Devices" on page 175).

Suitable holding devices must be used for preventing the axis from sinking after the power has been switched off. Adequate holding devices are integrated in most of today´s weight compensation systems. These holding devices can be actuated electrically, pneumatically or hydraulically.

- On vertical axis, the use of an absolute measuring system is recommended.
- Incremental measuring systems can only be used, if additionally to the holding device
  - a Hall sensor box is used (see chapter 7 "Accessories and Options" on page 111).
  - a saturation procedure can be used for commuation adjustment. That means, the control device makes maximum current of the motor available.

    See also chapter 9.16.2 "Selection Criterias for Length Measuring System " on page 169.

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.

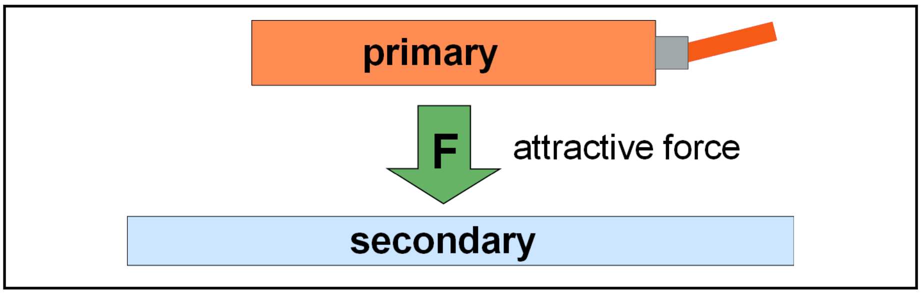

Fig.9-29: Attractive force between primary and secondary part

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

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⚠ 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 27.

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.

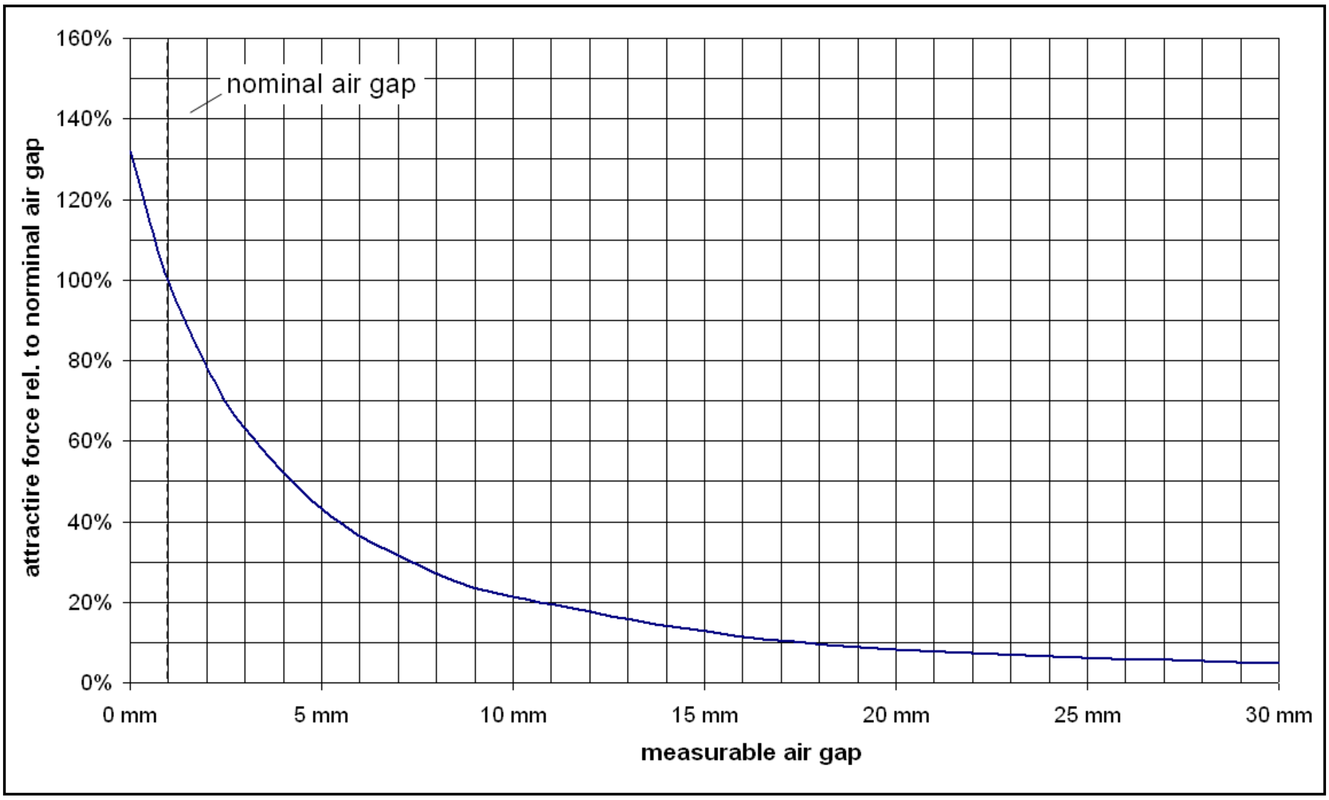
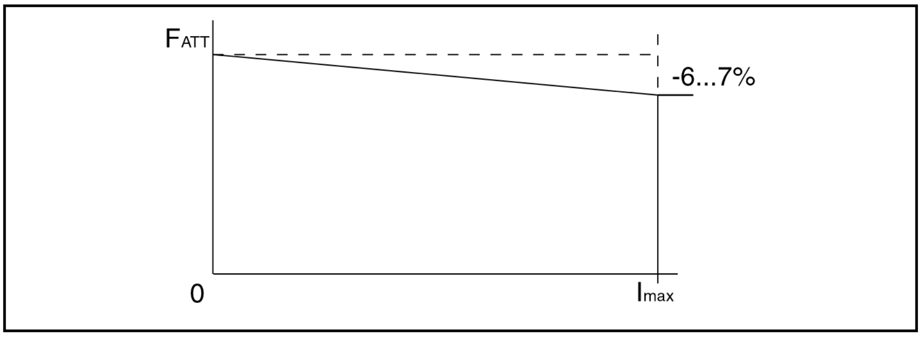


Fig.9-30: Attractive force vs. distance between primary and secondary part

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:

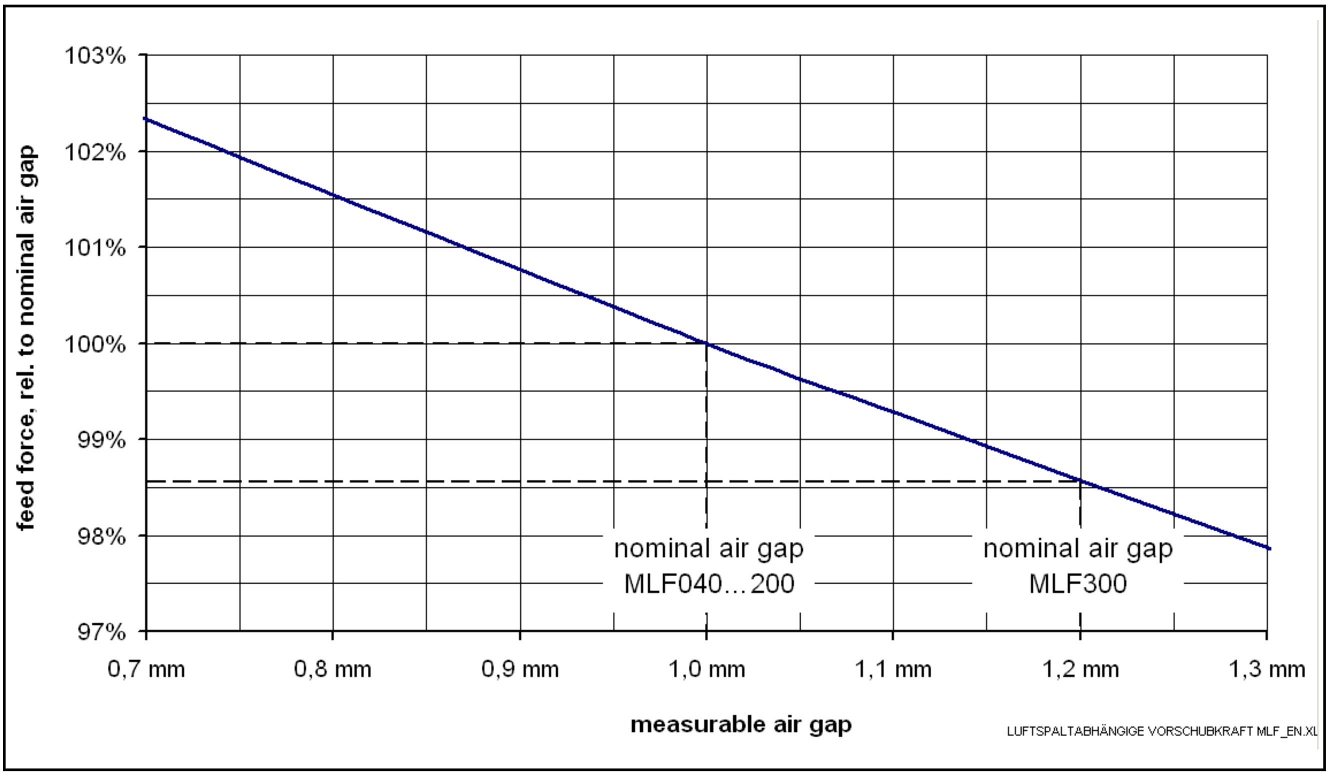


Fig.9-32: Feed force within the air gap tolerance of synchronous linear motors IndraDyn L.

☞ The sizes in Fig. 9-32 are only valid for IndraDyn L synchronous linear motors and there is no general correlation for other motor types.

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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, a reduced feed forces and attractive forces result.

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.

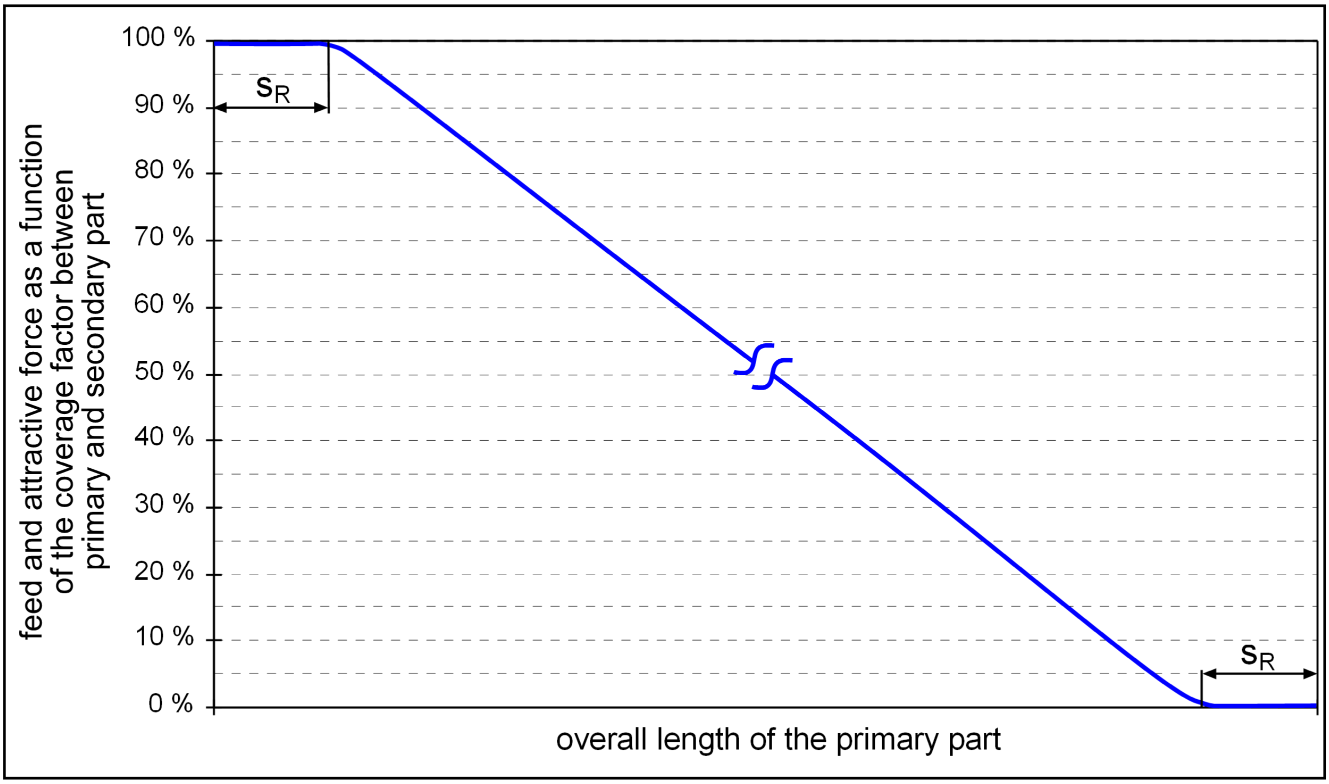


Fig.9-33: Force reduction with partial coverage of primary and secondary part

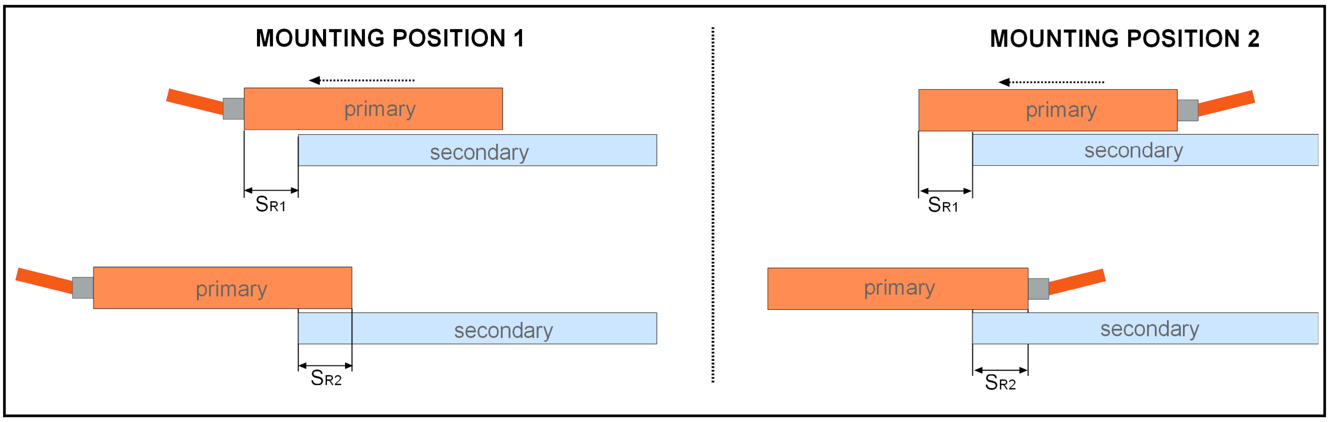


Fig.9-34: Presentation of force reduction with regard to Fig. 9-33

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

9.6.1 General Information

Rexroth IndraDyn L kit motors have a closed oolant circuit. The motor power loss P_V transformed to heat is dissipated using the cooling circuit. The cooling system must be rated by the machine manufacturer such that all requirements regarding flow, pressure, cleanliness, temperature gradient, etc. are maintained in every operating state.

⚠ CAUTION **Impairment or failure of motor, machine or cooling system!**

- Observe the manufacturer's instructions when designing and operating cooling systems.
- Do not use coolants or cutting materials from machining processes.
- Avoid contamination of the cooling medium as well as modifications of chemical composition and pH.
- Observe the notes and limitations for operating motors without liquid cooling under chapter 9.6.5 "Operation of IndraDyn L synchronous linear motors without liquid cooling" on page 151.

Materials Used

The coolant medium gets in contact with the following materials in the primary part:

Component MLP...	coolant ducts	Screw connections
040 ... 300	Copper (Cu)	Brass (CuZn39Pb2)

Fig.9-36: Materials coming into contact with the coolant

Application and Construction Instructions

In dimensioning and operating the cooling system, the machine manufacturer has to exclude all chemical or electro-chemical interactions with subsequent corrosion or disintegration of motor parts.

9.6.2 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 loss of synchronous linear motors are defined almost exclusively because of the low relative velocities among primary and secondary part due to short-circuit loss of the primary part:

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

P_V	Total loss in W
P_{VI}	Short-circuit loss 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.9-37: Power loss of synchronous linear motors

> ☞ When you determine the power loss according to Fig. 9-37 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. 9-38) 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. 9-39 and Fig. 9-41 are used to define the operating modes, e.g. acc. to DIN EN 60034-1.

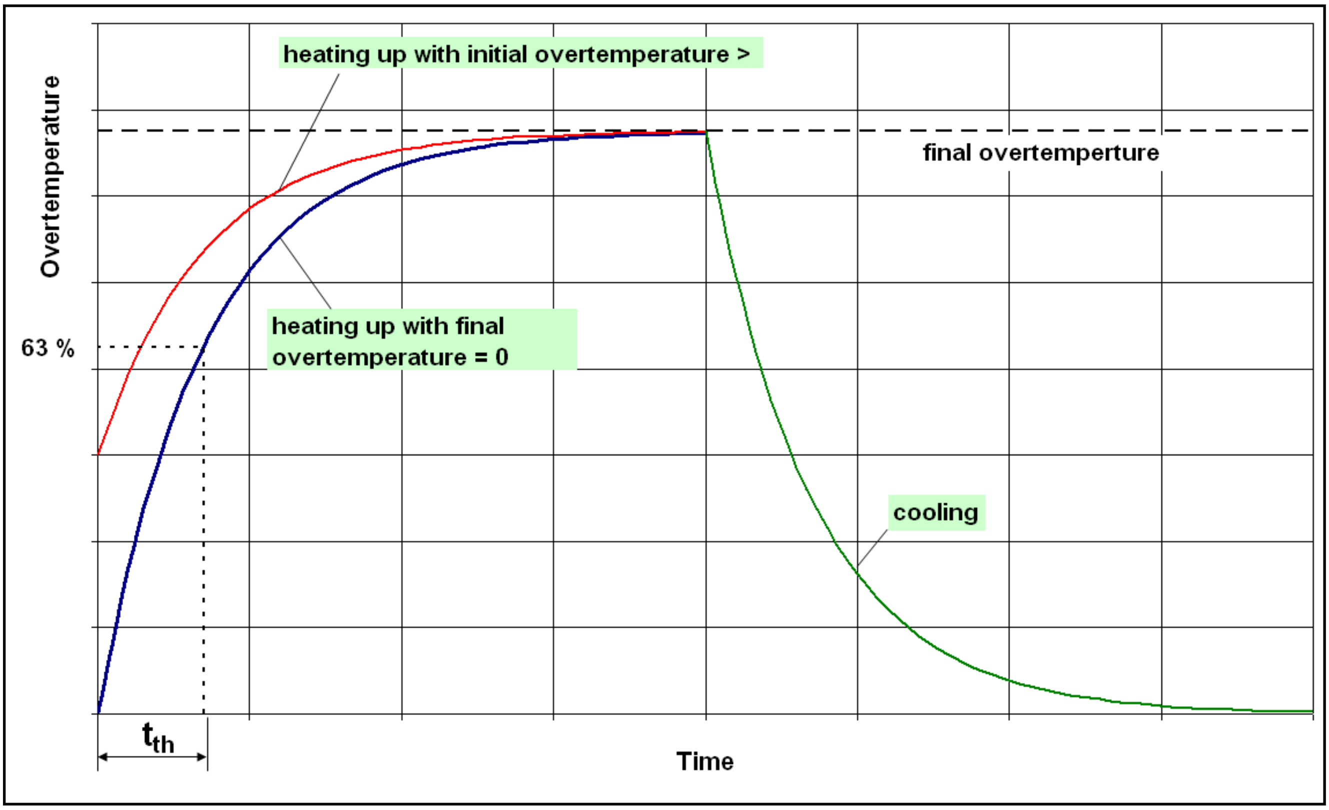


Fig.9-38: Heating up and cooling down of an electrical machine

Heating Up

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

ϑ_e	Final over temperature in K
ϑ_a	Initial over temperature in K
t	Time in min
t_{th}	Thermal time constant in min (see Chapter 4 ”Technical Data)

Fig.9-39: 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 ϑ_e can be estimated according to Fig. 9-40:

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

P_{ce}	Continuous power loss or average power loss over cycle duration in W (see Chapter 11.4)
P_{vN}	Nominal power loss of the motor in W
ϑ_{emax}	Maximum final over temperature of the motor in K
F_{eff}	Effective force in N (from application)
F_{dn}	Continuous 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.9-40: Expected final over temperature of the motor

Cooling Down

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

ϑ_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.9-41: Cooling down of an electrical machine

9.6.3 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. 9-42).

☞ 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.

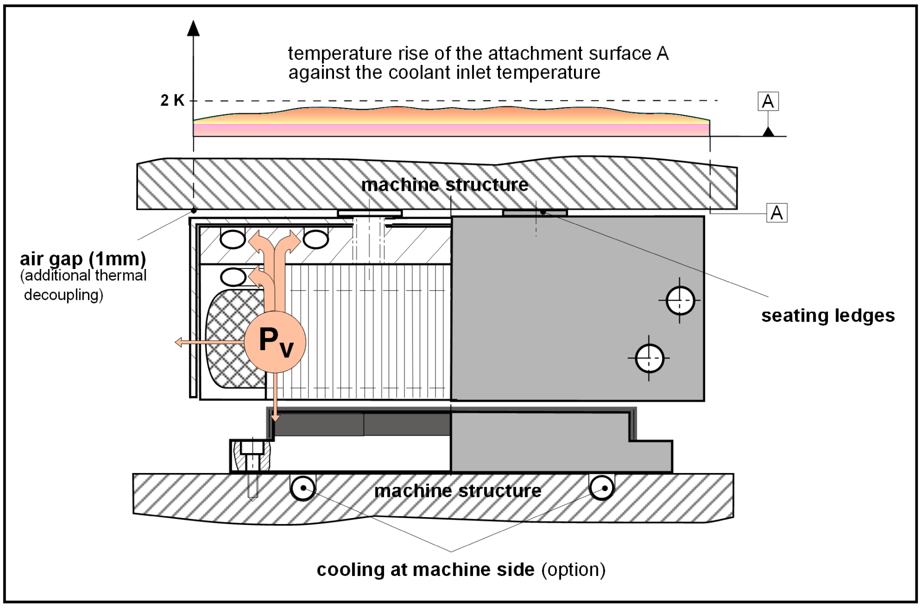


Fig.9-42: Cooling concept for thermal encapsulation

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 (see Fig. 9-42).

9.6.4 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

Cooling with running water from the public supply network is not allowed. Hard water may cause precipitations or corrosion and damage both motor and 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.

If the coolants, additives or cooling lubricants used are too aggressive, the motors may be damaged to an irreparable degree.

- 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 at regular intervals as specified in the machine and cooling system manufacturer's maintenance schedule.

Note that the utilization of unsuitable cleaning agents may cause irreversible damage to 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! Loss of warranty!**

⇒ Only use fluids or materials for cleaning and cooling the motor, which do not attack the motor cooling system and do not react aggressively to the materials we use.

⇒ 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

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	Order code	Additives NALCO...
0.5 ... 50	Nalco PCCL100.11R	PCCL100

Fig.9-43: Ready-to-Use Cooling Water (Company NALCO)

Cooling 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 proper treatment concentration.

Nalco PCCL100 contains a corrosion inhibitor protecting ferrous metal, 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	Order code	Additives NALCO...
50 ... 100	480-BR100-100.88	TRAC100 7330 73199
100 ... 200	480-BR100-200.88	
200 ... 350	480-BR100-350.88	
350 ... 500	480-BR100-500.88	

Fig.9-44: 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 protecting ferrous metal, copper alloys and aluminum 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 suitable 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

Planckstr. 26

71691 Freiberg/Neckar, Germany

Fax +49(0)7141-703-239

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 Fig. 9-45:

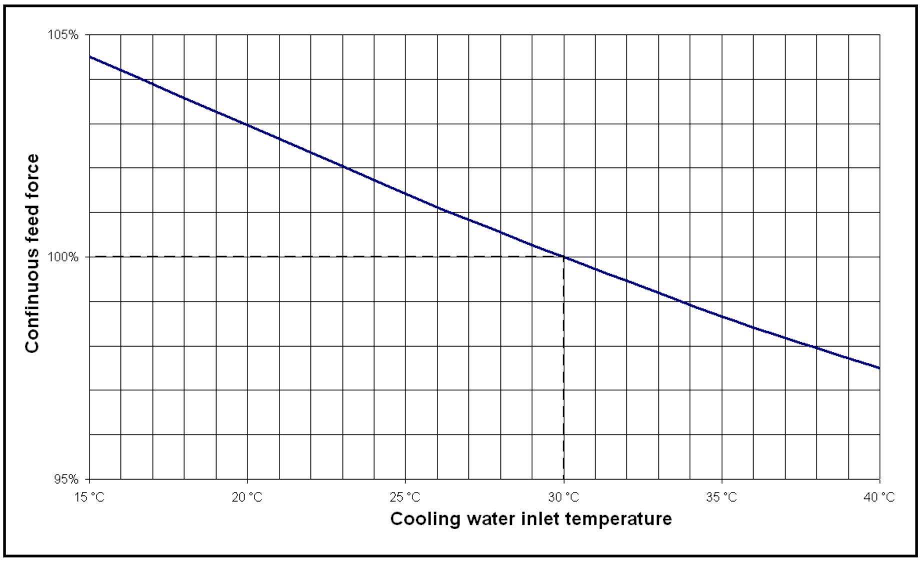


Fig.9-45: Continuous feed force vs. coolant flow temperature

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.

9.6.5 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

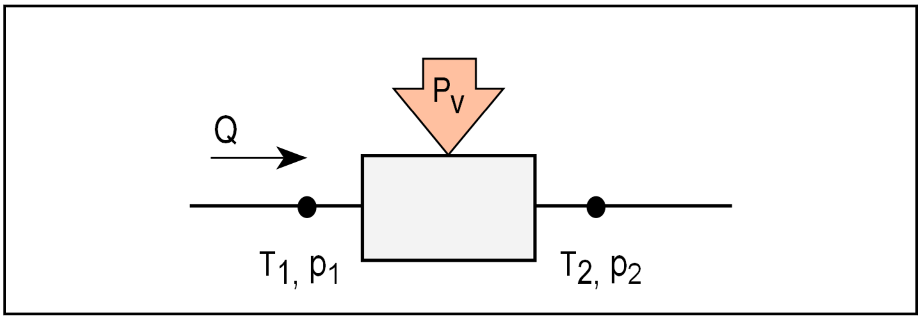
⇒ The reduction of the rated force and the heating of the machine structure (stress due to expansion) must be included in the sizing and design of axes that are used without liquid cooling.

⇒ 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 withinchapter 13.4 "Parameterization " on page 244 about operating an IndraDyn L synchronous linear motor withour liquid cooling.

9.6.6 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.9-46: 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
ΔT	Coolant temperature rise in K

Fig.9-47: Coolant temperature rise in K

Pressure Drop

$$\Delta p = p_1 - p_2$$

p_1	Inlet pressure
p_2	Outlet pressure
Δp	Pressure drop

Fig.9-48: 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. 9-49 and Fig. 9-50 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
ρ	Density of the coolant in kg/m³
ΔT	Coolant temperature rise in K

Fig.9-49: 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	4,183	998.3
Thermal oil (example)	1,000	887
Air	1,007	1.188

Fig.9-50: 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

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formula acc. to Fig. 9-51 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. ΔT_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
ΔT_m	Temperature rise on contact surface in K

Fig.9-51: 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. 9-46).

The pressure drop Δp rises as the flow quantity rises (Fig. 9-52).

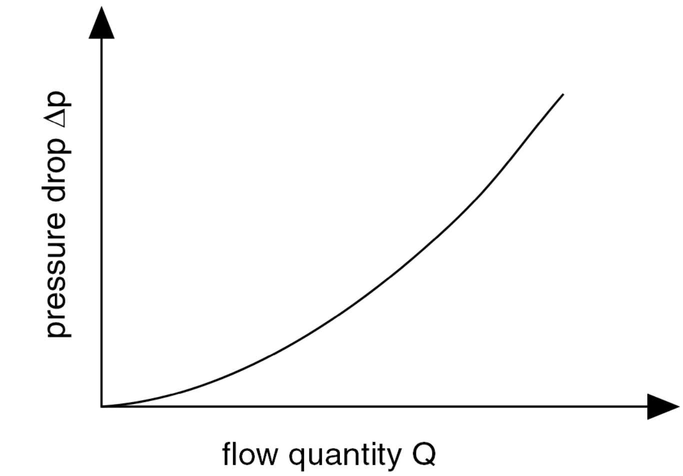


Fig.9-52: Pressure drop vs. flow quantity; general representation

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:

$$\Delta p_m = k_{dp} \cdot Q^{1.75}$$

Δp_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.9-53: 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. 9-54). Usually, the pressure drop across the internal motor cooling system is relatively small.

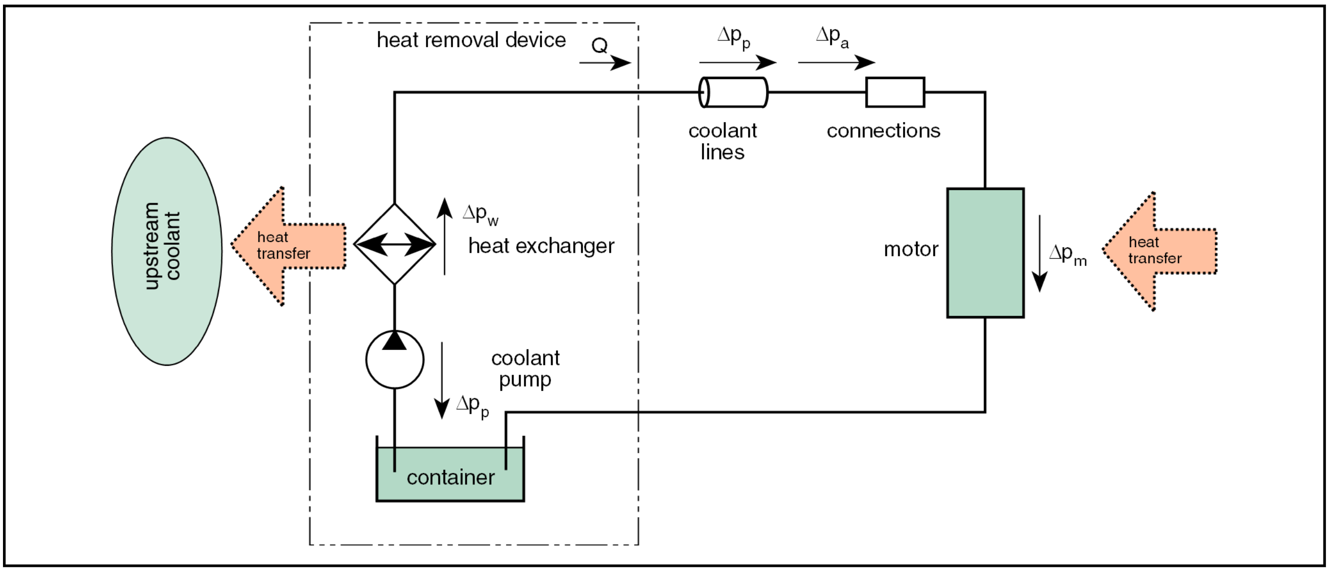


Fig.9-54: General arrangement of a liquid cooled motor with heat removal facility

☞ 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.

9.6.7 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.

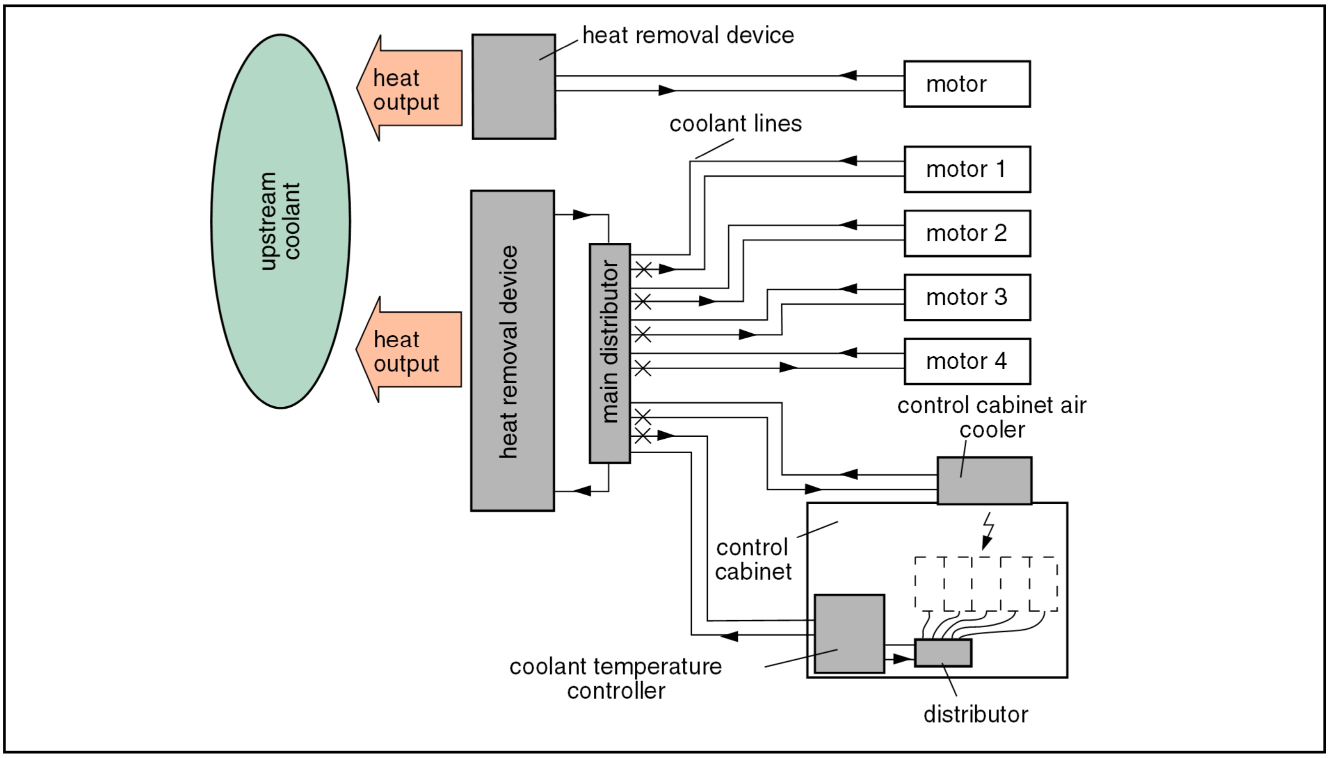


Fig.9-55: General arrangement of cooling systems with one and more drive components

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**

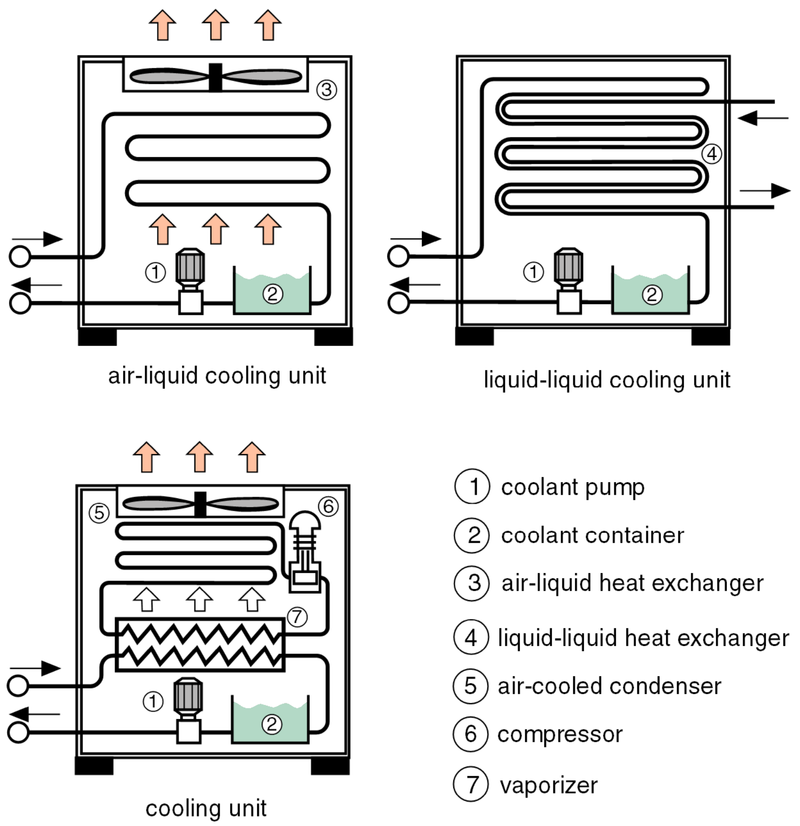


Fig.9-56: Heat removal devices

	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 an 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. Id 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.9-57: Overview of the heat removal devices according to utilization criteria

Application and Construction Instructions

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

  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
- Choke 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

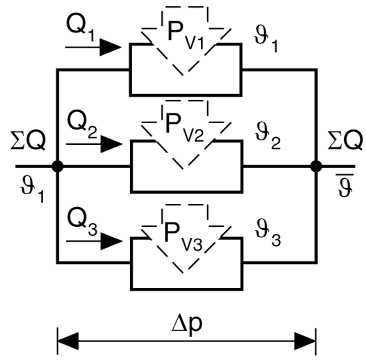


Fig.9-58: Parallel connection of liquid-cooled drive components

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.9-59: 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

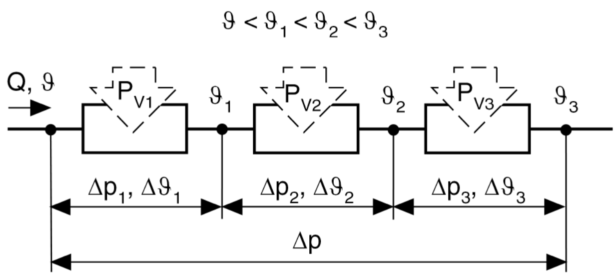


Fig.9-60: Series connection of liquid-cooled drive components

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.9-61: 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.

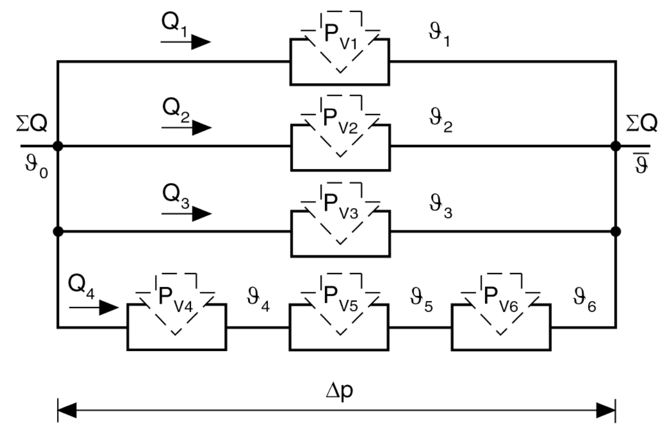


Fig.9-62: Combination of series and parallel connection

Application and Construction Instructions

9.7 Motor Temperature Monitoring

⚠ CAUTION **Failure in the machine or damage by improper use of the sensors!**

- The PTC sensors are no safety devices and are not suitable for integration into safety systems to protect persons or machines.
- The PTC sensors are neither designed nor suitable for registering the temperatures of housing, rotor or motor bearing. Additional temperature control requirements must be realized by the machine manufacturer.
- To ensure safe motor protection against thermal overload, temperature sensor SNM150.DK must be connected to the drive controller.

In their standard configuration, primary parts of IndraDyn L motors are equipped with built-in motor protection temperature sensors. Every motor phase contains one out of three series ceramic PTCs, so that reliable thermal monitoring of the motor is possible in every operation phase. These temperature sensors (referred to as motor protection temperature sensor below) have a switching characteristic (Fig. 9-12) and are evaluated on all Rexroth drive controllers.

Furthermore all primary parts with an additional temperature sensor for temperature measurement. This sensor (referred to as temperature measurement sensor below) has an approximately linear characteristic curve (Fig. 9-67).

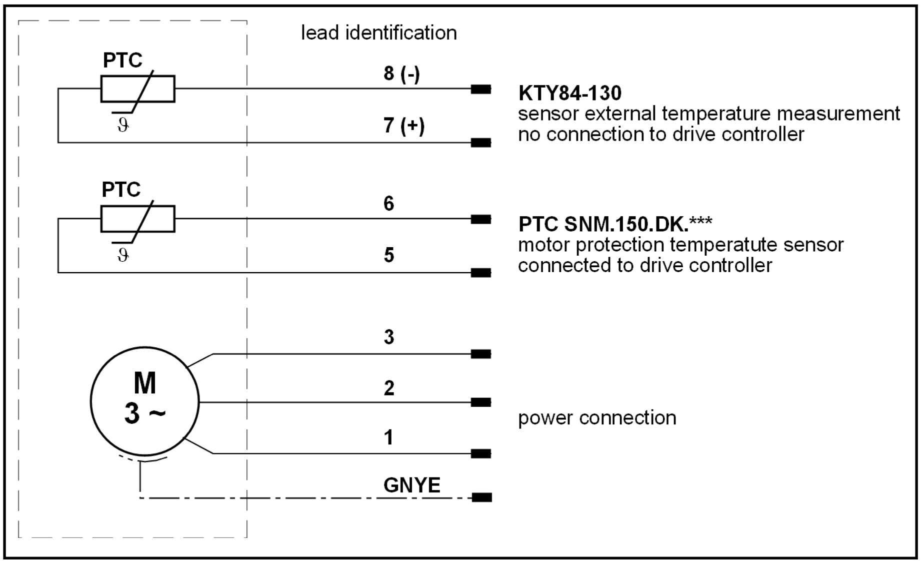


Fig.9-63: Arrangement of temperature sensors at IndraDyn L motors

Motor protection temperature sensor

Type	PTC SNM.150.DK.***
Rated response temperature ϑ_{NAT}	150 °C
Resistance at 25 °C	≈ 100 ... 250 ohms

Fig.9-64: Motor protection temperature sensor

☞ For the parallel arrangement of two or more primary parts, the motor protection temperature sensors of all primary parts are connected in series.

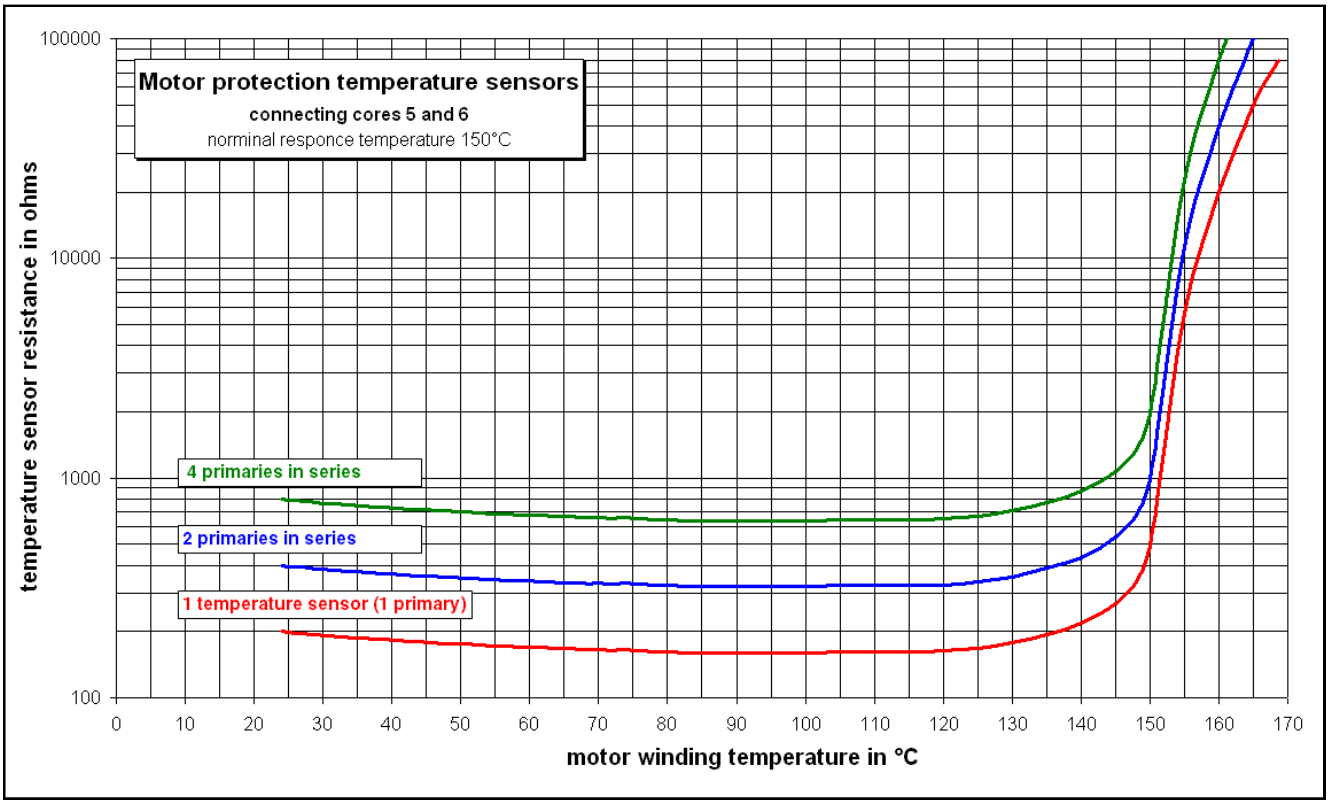


Fig.9-65: Characteristic of motor protection temperature sensors (PTC)

External temperature measurement sensor

Type	PTC KTY84-130
Resistance at 25 ℃	577 ohms
Resistance at 100 ℃	1000 ohms
Continuous current at 100 °C	2 mA

Fig.9-66: External temperature measurement sensor

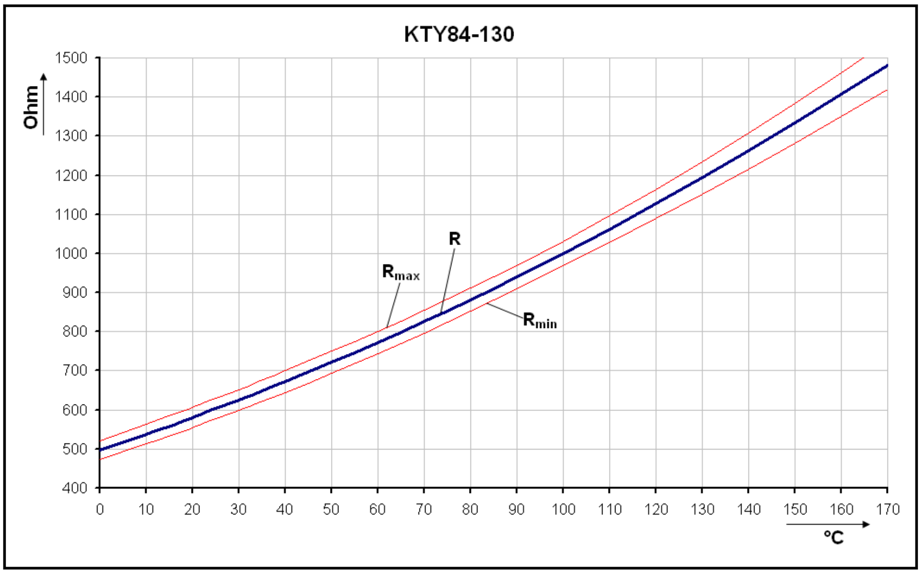


Fig.9-67: Characteristic of temperature measurement sensor KTY84-130 (PTC)

A polynomial of degree 3 is sufficiently precise for describing the resistance characteristic of the sensor used for temperature measurement (KTY84-130). In the following, this is specified for determining a temperature at a given resistance and vice-versa.

Temperature in relation to the 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
$A = 3.039 \cdot 10^{-8}$
$B = -1.44 \cdot 10^{-4}$
$C = 0.358$
$D = -143.78$

Fig.9-68: Polynomial used for determining the temperature with a known sensor resistance (KTY84)

Resistance in relation to the 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
$A = 1.065 \cdot 10^{-6}$
$B = 0.011$
$C = 3.93$
$D = 492.78$

Fig.9-69: Polynomial used for determining the sensor resistance (KTY84) with a known temperature

☞ Ensure correct polarity when using the sensor for temperature measurement.

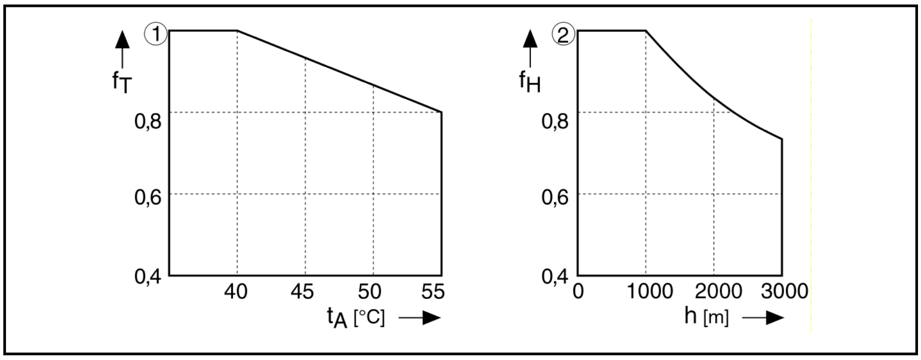
For more information on connecting the temperature sensors, please refer to chapter chapter 8.2.1 "Temperature Sensors" on page 121.

9.8 Setup Elevation and Ambient Conditions

The motor performance data specified are applicable for

- 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 installation altitude at the same time, both utilization factors must be multiplied.



①	Utilization depending on the ambient temperature
②	Utilization depending on the installation altitude
f_T	Temperature utilization factor
t_A	Ambient temperature in degrees Celsius
f_H	Height utilization factor
h	Installation altitude in meters

Fig.9-70: IndraDyn L utilization factors

If **either** the surrounding air temperature **or** the installation altitude is above the nominal data:

1. Multiply the motor data specified in the technical data by the determined utilization factor.
2. Ensure that the reduced torque data are not exceeded by your application.

If **both** the surrounding air temperature **and** the installation altitude are above the nominal data:

1. Multiply the determined utilization factors f_T and f_H.
2. Multiply the resulting value by the motor data specified in the technical data.

Ensure that your application does not exceed the reduced motor data.

☞ The details for the utilization against the installation altitude 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 Air Temperature / Air Humidity

Climatic environmental conditions are defined according to different classes as specified in DIN EN 60721-3-3, Table 1. They are based on long-term experiences and take all influencing variables into account, e.g., air temperature and air humidity.

Based on this table, Rexroth recommends class 3K4 for continuous use of the motors.

The following table provides extracts from this class.

Environmental factor	Unit	Class 3K4
Low air temperature	°C	+5 ①
High air temperature	°C	+40
Low rel. air humidity	%	5
High rel. air humidity	%	95
Low absolute air humidity	g/m³	1
High absolute air humidity	g/m³	29
Temperature change rate	°C/min	0,5

① The lowest air temperature allowed by Rexroth is 0°C.

Fig.9-71: Classification of climatic ambient conditions according to DIN EN 60721-3-3, Table 1

9.10 Degree of Protection

The design of IndraDyn L synchronous linear motors corresponds to the protection mode according to DIN EN 60034-5:

Motor components	Degree of protection
Primary part with standard encapsulation Primary part with thermo encapsulation Secondary part	IP65

Fig.9-72: 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.9-73: 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.

9.11 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.

9.12 Magnetic Fields

The secondary parts of synchronous linear motors are equipped with permanent magnets, which are not magnetic shielded.

Personal Protection

⚠ WARNING **Electromagnetic / magnetic fields! Health risk for persons with pacemaker, metallic implants or hearing devices! Material damage.**

Danger due to magnetic and electromagnetic fields on live conductors or permanent magnets of electro motors.

Persons with pacemakers and metallic implants must keep away from these motor parts.

Access to areas, in which such drive components are mounted and operated, is not allowed for the named persons. It is allowed after consulting a doctor, only.

Keep watches, credit cards, check cards and identity cards with magnetic strips and all ferromagnetic parts away from magnetic fields.

No worldwide consistent and binding standard, regulation or direction exists, in which explicite instructions or specifications for carriers of active medical implants or pregnant women in expositions areas with electric, magnetic or electromagnetic fields are specified. Regional directives, guidelines and standards (e.g. BGV B11 of the German trade association, DIN EN 50527, DIN VDE 0848, etc.) or recommendtions of non-proprietary organizations (e.g. ICNIRP) exist.

The directive 2004/40/EG on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents specifies the maximum exposure limit values of the ICNIRP directives for professional exposition in the European Union (EU). The European Directive

2004/40/EG additionally obliges employers, during risk assessment, even to analyse indirect influences like influence (malfunction) of medical electronical or electric devices (including pacemakers and other metallic implants). Therefore, observe the present specific characteristics of active medical implants in individual cases (e.g. device mode, different stability classes) and electric and magnetic fields which are effective on the machine. They can be different in every single case and can be determined on the respective machine depending from the construction of the machine, type, amount, arrangement and operating mode of mounted electromagnetic-fields-radiating devices.

A general valid statement about reliability or suitability of pacemakers or other active medical implants or danger for pregnant women in these explosive areas cannot be given by Bosch Rexroth. Basically, health risks cannot be excluded. Generally, Bosch Rexroth does not allow employees with active medical implants like heart pacemakers, defibrillators, a.s.o and pregnant women to work in such explosive areas. This is clearly signaled by a warning label, which is stuck on the outside of every package with open permanent-magnet-parts.

☞ Secondary parts of IndraDyn L motors generate a static magnetic field. The machine manufacturer (OEM) or user must determine and decide by himself, which guideline and directive must be observed for machine construction and the user manual for the machine and how working protective measures must be converted on the machine.

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.

Air freight (IATA953)

For shipping secondary parts MLS as air freight, limit values (according to IATA953) for magnetic flow density in all room directions must be kept:

Distance of edge of package	Flow density	Measure
2.1 m	≤ 0.525 µT	Package can be sent without declaration and designation.
4.6 m	≤ 0.525 µT	Declaration and designation as magnetic material necessary.
4.6 m	≥ 0.526 µT	Shipping only with pre-approval of the responsible national authority of the state of departure and the state of the airline.

Fig.9-74: Limit values of magnetic flow density for air freight

9.13 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. 9-75 and Fig. 9-76 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.9-75: 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.9-76: 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. 9-75 and Fig. 9-76 for storage, transport, and operation of the motors are not exceeded.

9.14 Housing Surface

The following table shows the condition of the enclosure surface when delivered.

Motor component	Housing surface
Standard encapsulation primary part	Stainless steel V4A
Thermal encapsulation primary part	Stainless steel V4A
Secondary part segments	Cover sheet stainless steel V4A Magnet base carrier C45, chromatic

Fig.9-77: Layout of enclosure surface

☞ It is possible to provide the surface of the motor components with varnish with a coat thickness no more than 40 µm. Check the adhesion and resistance of the varnish before applying it.

9.15 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.

9.16 Length Measuring System

9.16.1 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.

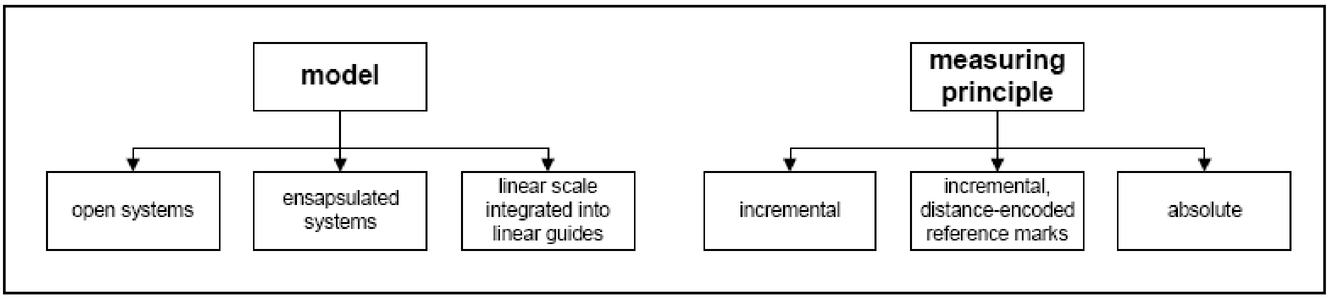


Fig.9-78: Classification of linear scales

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.

9.16.2 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 - High accuracy - No friction	- Easy installation - High protection class - Incremental and absolute measurement available	- Combined guidance and measurement - No additional installation required - Highest protection class - High traverse rates - Little space required

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Open model	Encapsulated model	Measuring system, integrated in rail guides
Disadvantage:		
- Low protection class - More complicated mounting and adjustment - Currently no absolute measurement systems available	- Maximum velocity currently 120m/min	- No absolute measurement systems available

Fig.9-79: 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.

Benefits

- 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.

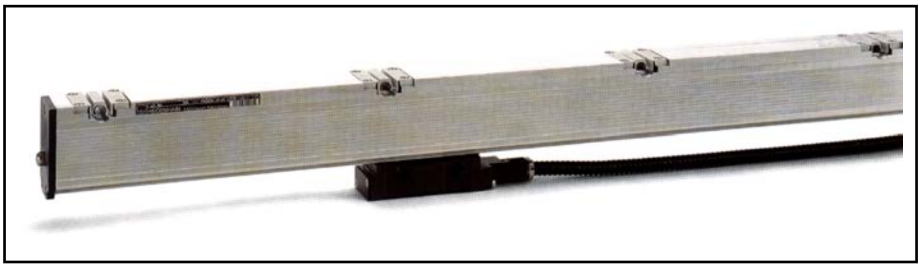

Fig.9-80: Absolute encapsulated length measuring system LC181

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 (commutation adjustment) must be executed upon each power-up.

Depending from the selected drive controller, in connection with an incremental scale, two different procedures for pole position recognition procedure.

- **Sinusoidal procedure** in connection with drive controllers with smaller type current als motor maximum current.

  Here, axis movment during commutation happens.

- **Saturation procedure** in connection with drive controllers with same or higher type current als motor maximum current.

  Here, no axis movement during commutation is necessary (axis can be locked)

Exact description of the commutation procedure see firmware description of drive controller and chapter 13.6 "Commutation Adjustment " on page 248.

Benefits

- 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.
- Movement of primary part at pole position acquisition necessary (only for sinusoidal procedure)
- Pole position acquisition for vertical axes only possible with saturation procedure

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- Pole position recognition is only possible for securely braked axes or for axes at the hard stop with saturation procedure.
- Pole position recognition of Gantry axes may cause problems
- Reference mark utilization and reference switch necessary
- 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).

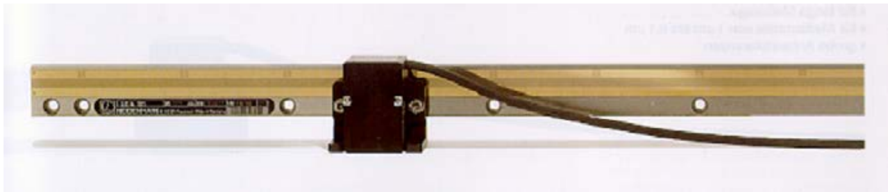


Fig.9-81: Open incremental linear scales LIDA185C with distance-encoded reference marks

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 evaluation electronic (DAG 1 VSS: 500 kHz) (DLF 1 VSS: 500 kHz)

Fig.9-82: 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

Bosch Rexroth recommends the following manufacturers for suitable length measuring systems in connection with our linear motors:

Bosch Rexroth Linar and Assembly Technique (Integrated measuring system for profiled rail guide)	Maria-Theresien-Str. 23 97816 Lohr am Main, Germany info@boschrexroth.de http://www.boschrexroth.com/business_units/brl/de/produkte/profilschienen_fuehrungen/ims/index.jsp
Renishaw GmbH	Karl-Benz Strasse 12 72124 Pliezhausen, Germany http://www.renishaw.com
DR. JOHANNES HEIDENHAIN GmbH	P. O. Box 1260 83292 Traunreut, Germany info@heidenhain.de http://www.heidenhain.de/

Fig.9-83: Recommended manufacturers of length measuring systems

☞
- 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 updated information.

9.16.3 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.

9.17 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

aufnehmen können.

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

9.18 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 14.1 "Recommended Suppliers of Additional Components " on page 261.

☞ Further designs about stand-still of linear motors are given in chapter 9.19 "End Position Shock Absorber " on page 175 and chapter 9.23 "Deactivation upon EMERGENCY STOPand in the Event of a Malfunction " on page 178 as well as in the appropriate functional description of the drive controller.

9.19 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.9-84: Braking distance to be kept when driving against end stop

9.20 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 14.1 "Recommended Suppliers of Additional Components " on page 261).

9.21 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 131).

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

Application and Construction Instructions

9.22 Drive and Control of IndraDyn L motors

9.22.1 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.

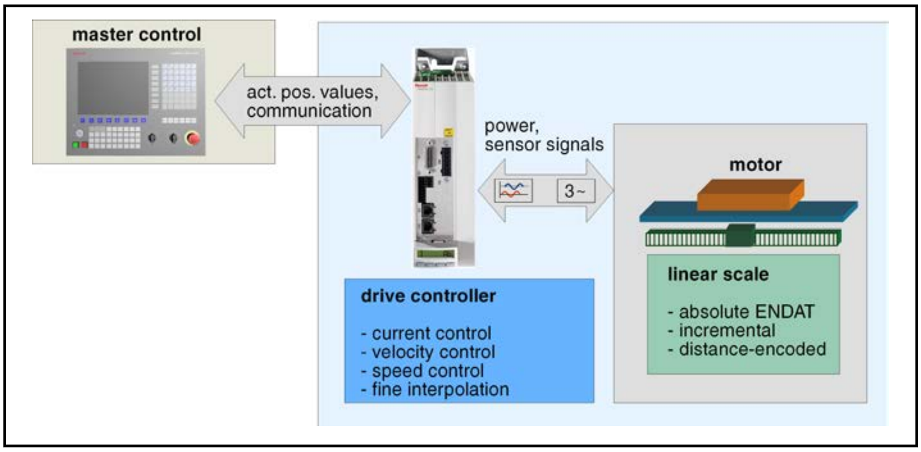


Fig.9-85: Linear direct drive

9.22.2 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.

9.22.3 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.

9.23 Deactivation upon EMERGENCY STOPand in the Event of a Malfunction

9.23.1 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

ausgelöst werden.

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.

getroffen werden.

9.23.2 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.

9.23.3 Deactivation by 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.

9.23.4 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-released) 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.

9.23.5 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 (capacitors), 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:

$$C_{add} = \frac{m \cdot v_{\max}}{U_{DC\max}{}^2 - U_{DC\min}{}^2} \cdot \left[3{,}5 \cdot \frac{F_{\max}}{k_{iF}{}^2} \cdot R_{12} - v_{\max} \cdot \left(\frac{F_R}{F_{\max}} + 0.3 \right) \right]$$

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.9-86: 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.

9.23.6 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.

9.24 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. 9-87, 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.9-87: Maximum rate of current and force rise

The acceleration change per time unit (derivative of the acceleration) is known as jerk (Fig. 9-90).

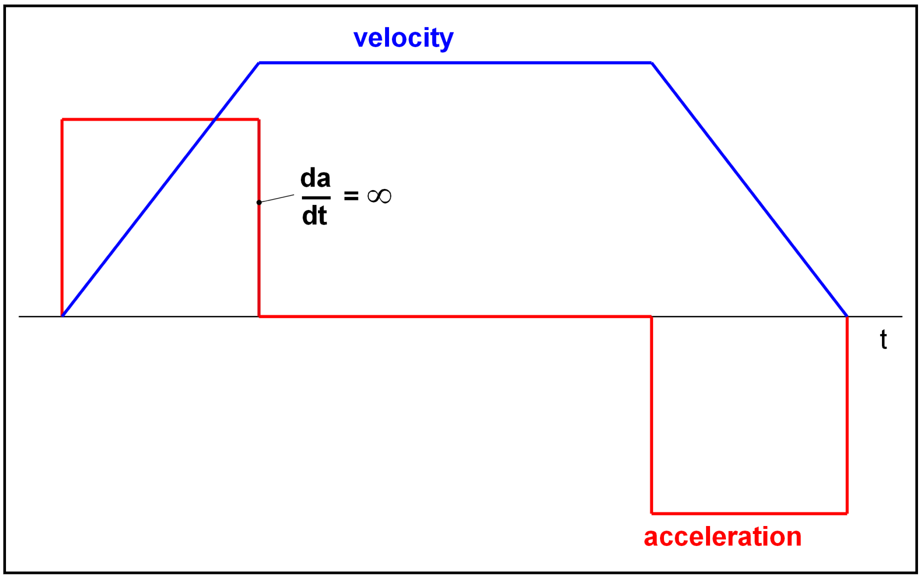


Fig.9-88: Acceleration and velocity without jerk limitation

☞ The drive controller or the master control must delimit the maximum jerk when direct drives are employed (acceleration ramp with da/dt ≠ ∞, Fig. 9-89).

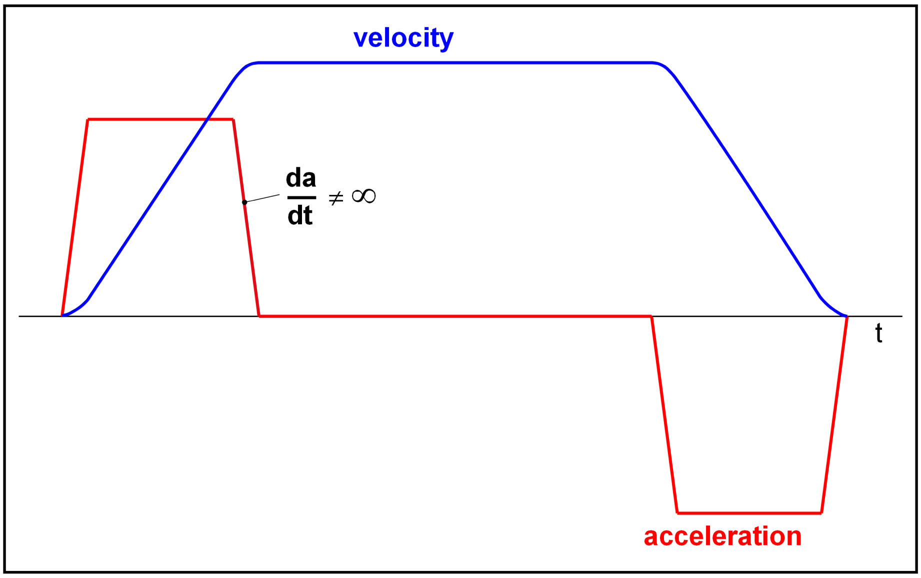


Fig.9-89: Acceleration and velocity with jerk limitation

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
l	Acceleration in m/s²
t	Time in s

Fig.9-90: Maximum jerk (acceleration change)

9.25 Position and Velocity Resolution

9.25.1 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. 9-92). 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).

$$f_{int} = 2^{31} \cdot \frac{s_p}{x_{max}} \qquad \text{rounding to } 2^n$$

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.9-91: Multiplication factor

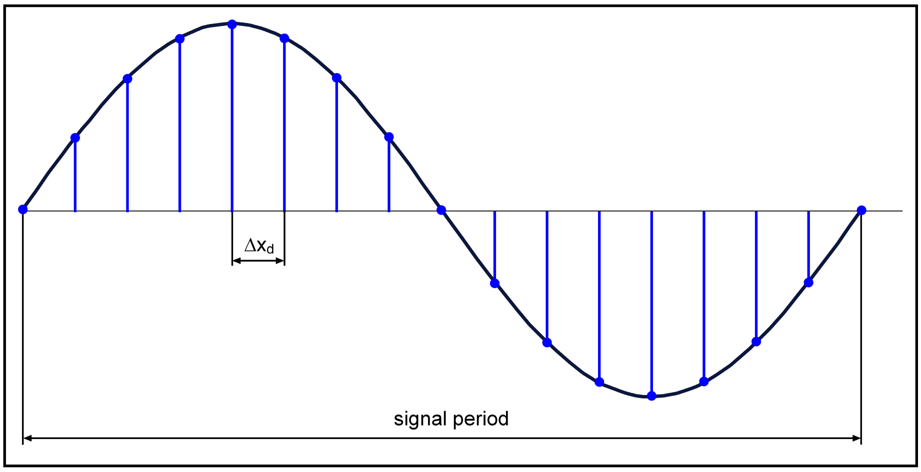


Fig.9-92: Drive-internal multiplication and/or interpolation of the measuring system signals

With a known signal period and a drive-internal multiplication, the drive-internal position resolution results as:

$$\Delta x_d = \frac{s_p}{f_{\text{int}}}$$

Δx_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.9-93: 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):

$$\Delta x_{abs} = \Delta x_d \cdot 30...50$$

Δx_d	Drive-internal position resolution
Δx_{abs}	Position accuracy

Fig.9-94: 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.

9.25.2 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:

$$\Delta v_d = \frac{\Delta x_d}{t_{AD}}$$

Δv_d	Velocity resolution in m/s
Δx_d	Drive-internal position resolution
t_{AD}	Sample time in s (ECODRIVE03: 500 µs; IndraDrive: Standard Performance 250 µs / High Performance 125 µs)

Fig.9-95: Velocity resolution

9.26 Load Rigidity

9.26.1 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.

9.26.2 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
Δx_D	Drive-internal position resolution in µm

Fig.9-96: 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
Δx_D	Drive-internal position resolution in µm

Fig.9-97: Static elasticity of linear direct drives

9.26.3 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. 9-99). 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.

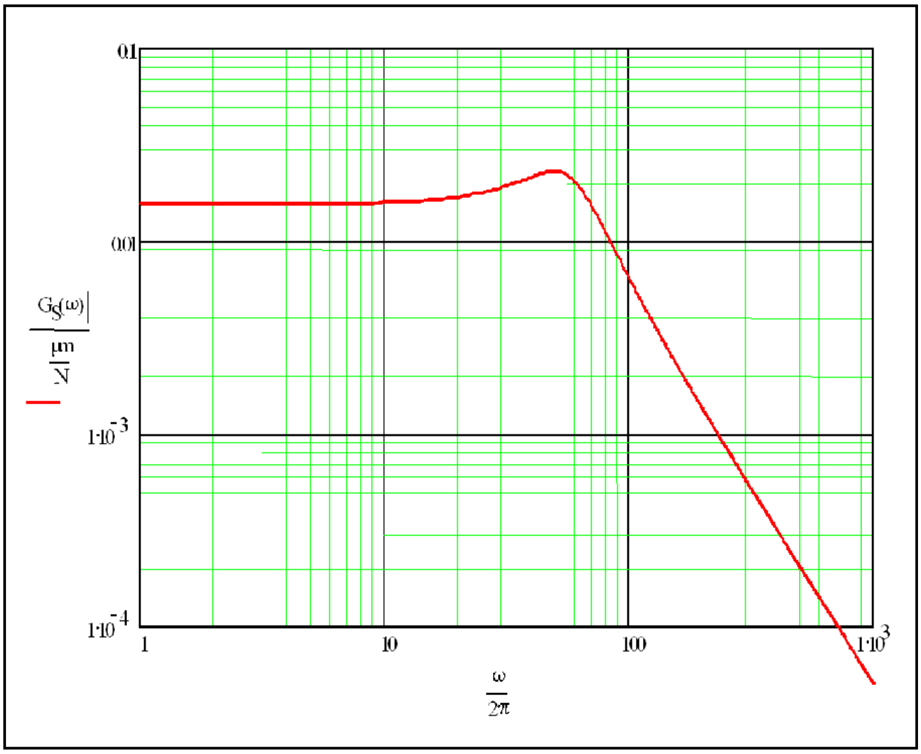


Fig.9-98: Example elasticity frequency response of a linear direct drive

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:

$$c_{dyn} = \frac{0.06 \cdot k_p \cdot k_{iF} \cdot (1 + 0.0167 \cdot k_v \cdot T_n)}{T_n \cdot \left(1 + \dfrac{e^{-D \cdot \frac{\pi}{\sqrt{1-D^2}}}}{\sqrt{1-D^2}}\right)}$$

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.9-99: 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.9-100:	*Determining of the dynamic elasticity*

$$\omega_0 = \frac{1}{2 \cdot \pi} \cdot \sqrt{\frac{1000 \cdot k_p \cdot k_{iF} \cdot (60 + k_v \cdot T_n)}{m \cdot T_n}}$$

ω_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.9-101:	*Determining the controller´s natural frequency*

10 Motor Dimensioning

10.1 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.

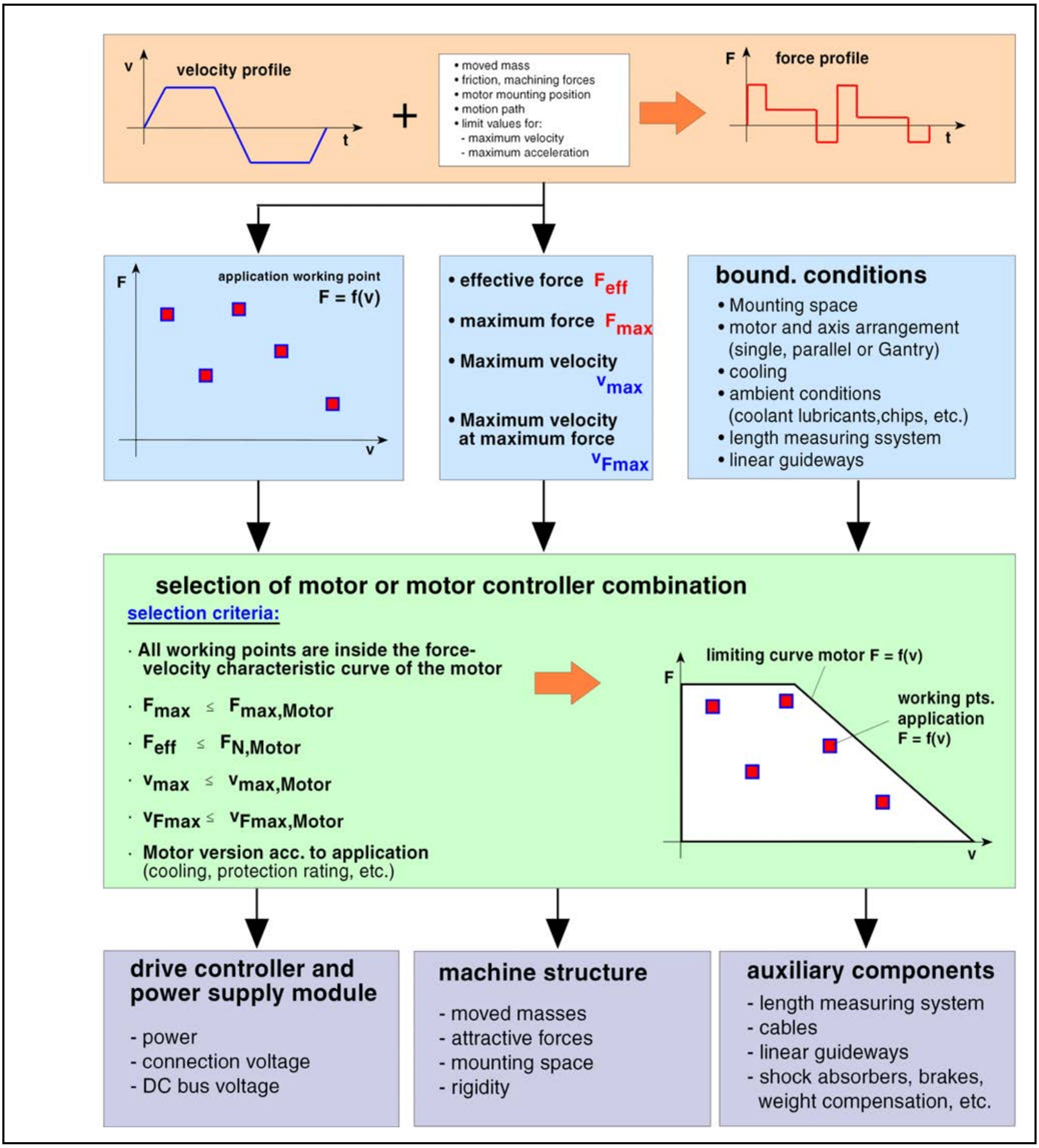


Fig. 10-1: Basic procedure of sizing linear drives

10.2 Basic Formulae

10.2.1 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. 10-2: 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.

10.2.2 Feed Forces

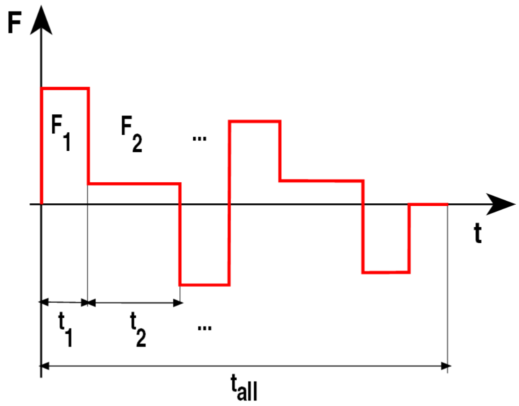


Fig. 10-3: Determining the feed forces

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
l	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. 10-4: 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.

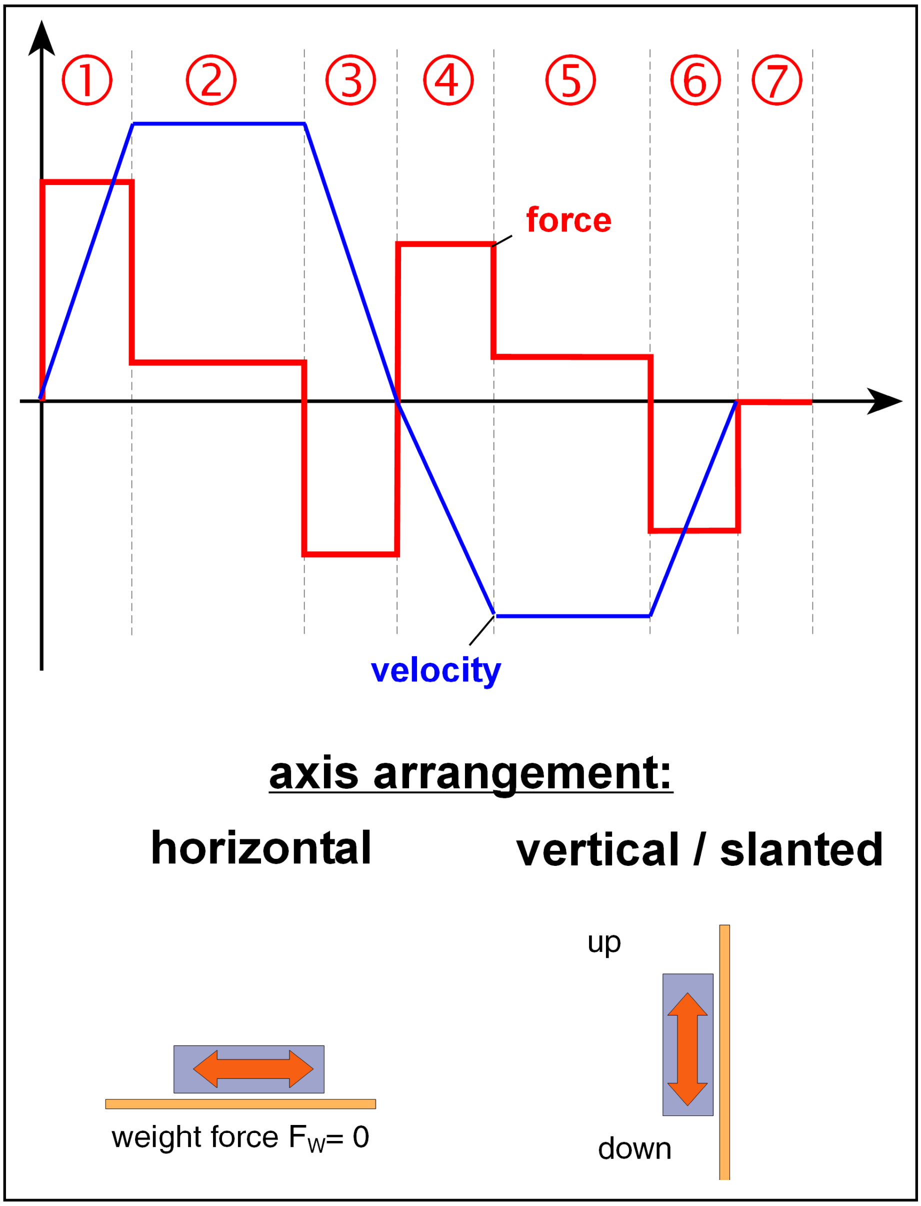


Fig. 10-5: Determining the resulting feed forces according to motion type and direction

(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.10-6: 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.

10.2.3 Average Velocity

The average velocity is required for determining the mechanical continuous output of the drive. Fig. 10-2 shows the general way of determining the average velocity. The following calculation can be used for a simple determination in trapezoidal or triangular velocity profiles:

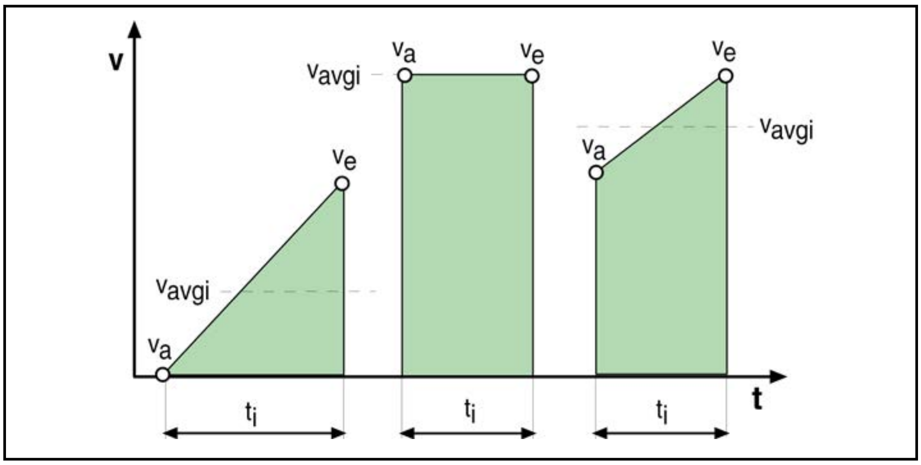


Fig. 10-7: Triangular or trapezoidal velocity profile

$$v_{avgi} = \frac{|v_a| - |v_e|}{2}$$

$$v_{avg} = \frac{\sum v_{avg\ i} \cdot t_i}{t_{all}}$$

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. 10-8: Determining the average velocity with triangular or trapezoidal velocity profile

10.2.4 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.

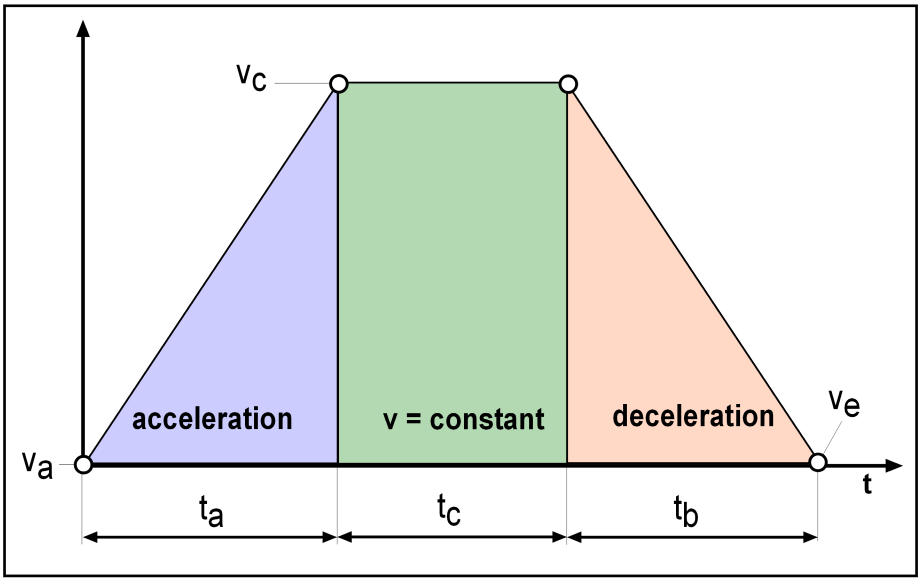


Fig. 10-9: Trapezoidal velocity profile

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: $$t_a = \frac{v_c}{a} = \frac{2 \cdot s}{v_c} = \sqrt{\frac{2 \cdot s}{a}}$$

l	Acceleration in m/s²
v_c	Final velocity in m/s
t_a	Acceleration time in s
c	Travel covered during acceleration in m

Fig. 10-10: Constantly accelerated movement, initial velocity = 0 (for trapezoidal velocity profile)

Motor Dimensioning

Acceleration, initial velocity ≠ 0

☞
- Velocity v ≠ constant
- Initial velocity $v_a \neq 0$
- 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: $$t_a = \frac{v_c - v_a}{a} = \frac{2 \cdot s}{v_c + v_a} = \frac{\sqrt{2 \cdot a \cdot s + v_a^2} - v_a}{a}$$

l	Acceleration in m/s²
v_c	Final velocity in m/s
v_a	Initial velocity in m/s
t_a	Acceleration time in s
c	Travel covered during acceleration in m

Fig. 10-11: 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. 10-12: Constant velocity (for trapezoidal velocity profile)

Brakes, Final Velocity = 0

☞
- Velocity v ≠ constant
- Final velocity $v_e = 0$
- Acceleration a = constant and negative

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: $$t_b = \frac{v_c}{a} = \frac{2 \cdot s}{v_c} = \sqrt{\frac{2 \cdot s}{a}}$$

l	Acceleration in m/s²
v_c	Final velocity in m/s
t_b	Braking time in s
c	Travel covered during acceleration in m

Fig.10-13: 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:
$$t_a = \frac{v_c - v_e}{a} = \frac{2 \cdot s}{v_c + v_e} = \frac{v_c - \sqrt{v_c^2 - 2 \cdot a \cdot s}}{a}$$

l	Acceleration in m/s²
v_c	Initial velocity in m/s
v_e	Final velocity in m/s
t_b	Braking time in s
c	Travel covered during acceleration in m

Fig. 10-14: Constantly accelerated movement, initial velocity ≠ 0 (for trapezoidal velocity profile)

10.2.5 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.

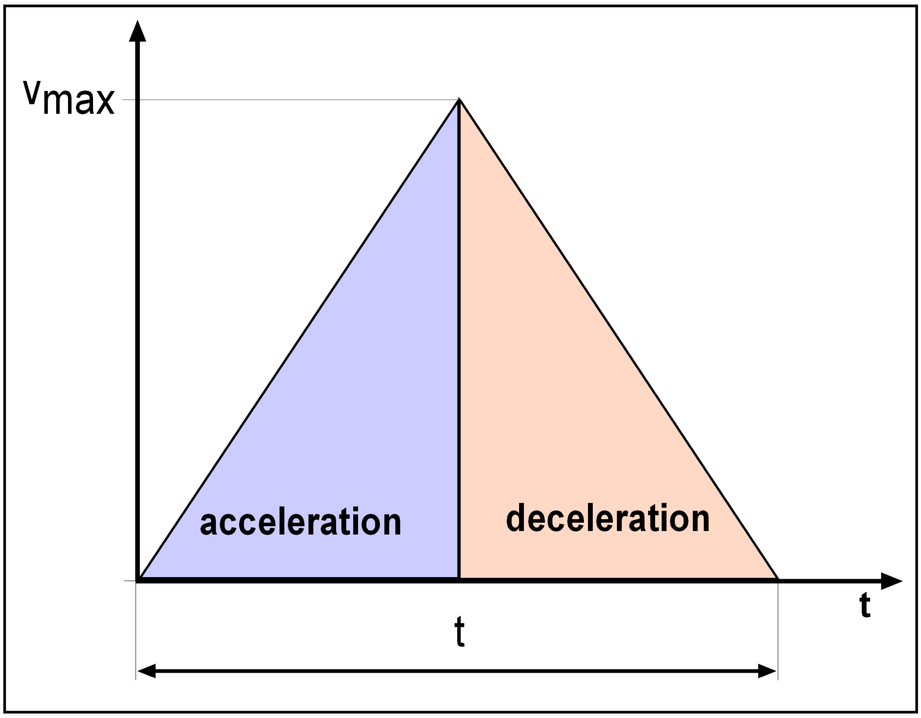


Fig. 10-15: Triangular velocity profile

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
l	Acceleration in m/s²
s_{all}	Total motion travel in m
t	Positioning time in s

Fig. 10-16: Determine triangular velocity profile

10.2.6 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.

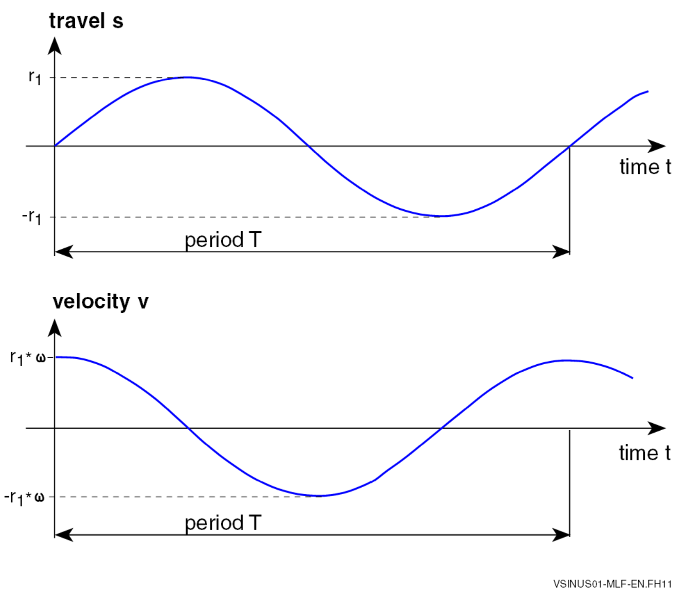


Fig. 10-17: Insert motion profiles of an axis at sinusoidal velocity.

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.10-18: Calculation formula for motion profiles of an axis at sinusoidal velocity.

The following calculation bases on Fig. 10-17 and Fig. 10-18

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. 10-19: Calculation formulae for sinusoidal velocity profile

☞ Further directional base and process forces must additionally be taken into account.

10.3 Duty Cycle and Feed Force

10.3.1 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. 10-20) in order to not thermally overload the motor at higher feed forces.

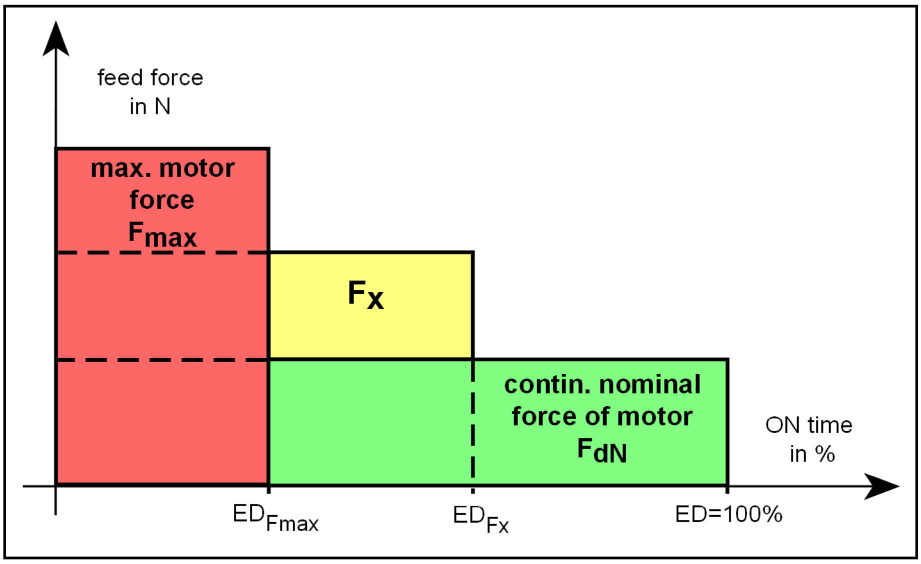


Fig. 10-20: Correlation between duty cycle and feed force

10.3.2 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. 10-21: Approximate determination of duty cycle ED

Prerequisites: Linear correlation between feed force and current.

For IndraDyn L motors acc. to Fig. 10-21, 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. 10-22 or Fig. 10-23 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. 10-21.

Use Fig. 10-22 or Fig. 10-23 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 dissipated rated power loss of the motor in W (for continuous power loss 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. 10-22: Determining the duty cycle ED

Prerequisites: Duty cycle time ≤ Thermal time constant of motor

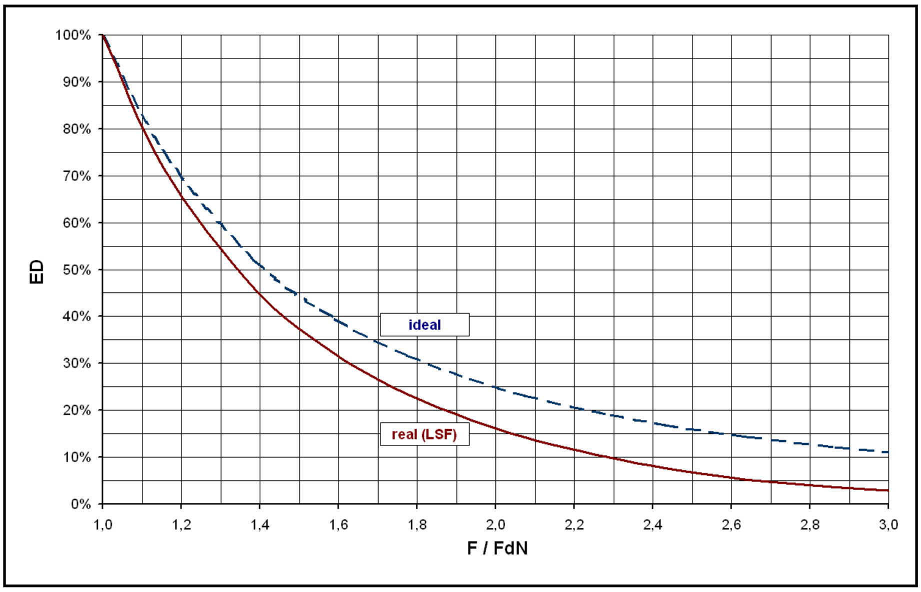


Fig. 10-23: Duty cycle vs. force for IndraDyn L synchronous linear motors

10.4 Determining the Drive Power

10.4.1 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.

10.4.2 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 continuous 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. 10-24: Rated power of the linear motor

☞ The rated electrical output (see Fig. 10-24) is reduced when the rated force is reduced.

10.4.3 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.

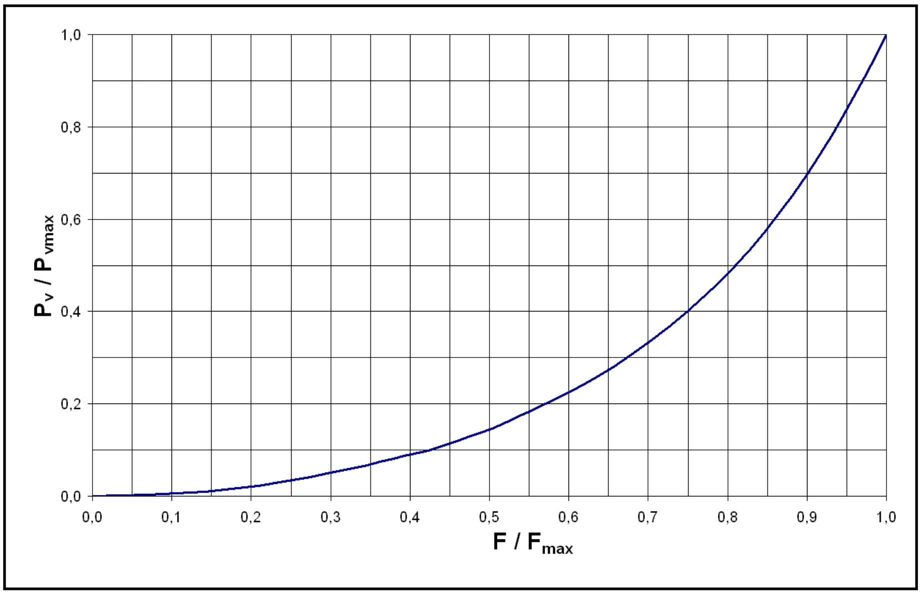
Total maximum power: $P_{max} = P_{max\,m} + P_{max\,e}$

Mechanical maximum power: $P_{max\,m} = F_{max} \cdot v_{F\,max}$

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. 10-25: 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. 10-26.



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. 10-26: Diagram used for determining the reduced electrical power loss

☞ The maximum power loss is specified in Chapter 10 ”Motor-Controller-Combination”.

10.4.4 Cooling Capacity

The necessary cooling capacity corresponds the electric continuous power loss of the motor.

$$\text{Required cooling capacity:} \quad P_{co} = P_{ce} = \left(\frac{F_{eff}}{F_{dn}}\right)^2 \cdot P_{vn} \quad with\ F_{eff} \leq F_{dn}$$

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. 10-27: Required cooling capacity of the linear motor

10.4.5 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.

$$P_R = \frac{m \cdot v^2}{2 \cdot t_b} - \frac{v \cdot F_R}{2} - \frac{3}{4} \cdot m^2 \cdot R_{12} \cdot \left(\frac{a_{max}}{k_{iFN}} \right)^2$$

$$P_{Ravg} = \frac{1}{T} \cdot \int_0^T P_R(t)\ dt = \frac{\sum P_{R\,i} \cdot t_{bi}}{t_{all}}$$

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	Braking 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. 10-28: 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. 10-28 is negative, energy is not fed back. This means that energy must be supplied to the motor during the deceleration process.

10.5 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. 10-29 and Fig. 10-30 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. 10-29: Determining the efficiency of linear motors

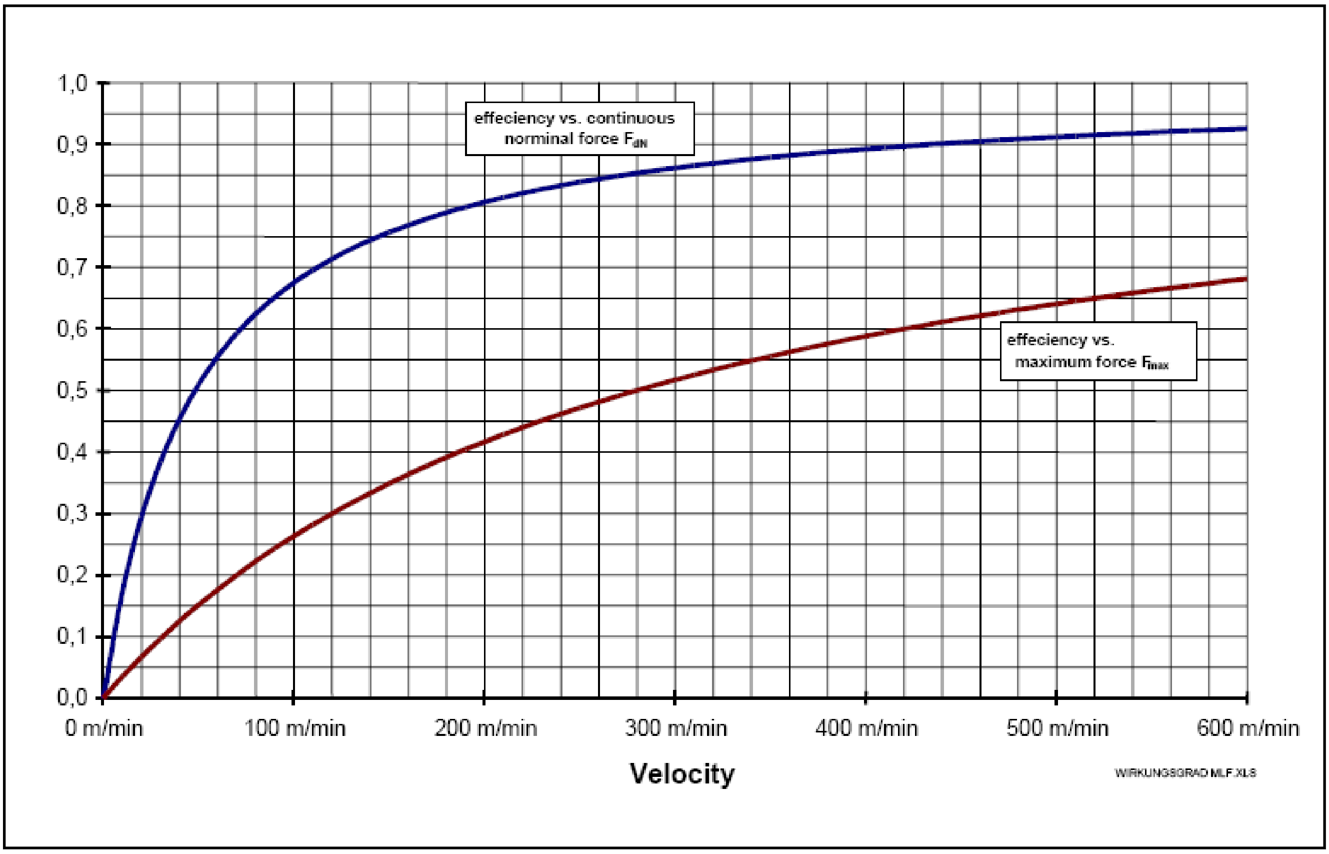


Fig.10-30: Efficiency vs. velocity for IndraDyn L synchronous linear motors.

10.6 Sizing Examples

10.6.1 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	Remark
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. 10-31: 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} = 14,400 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. 10-32: 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. 10-33: Moved total mass

$$F_0 = F_F + F_{zus}$$
$$F_0 = \mu \cdot (m_{ges} \cdot g + F_{ATT}) + F_{zus}$$
$$F_0 = 0.005 \cdot (84\,kg \cdot 9.81\,m/s^2 + 14400\,N) + 150\,N$$
$$F_0 = 226\,N$$

Fig.10-34: Base force

$$F_W = 0\,N$$

Fig.10-35: 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.10-36: Acceleration force

$$F_{max} = F_{acc} + F_0$$
$$F_{max} = 2100\ N + 226N$$
$$F_{max} = 2326\,N$$

Fig.10-37: 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.10-38: Total time or duty cycle time

Velocity and force profile

The selected velocities and the determined forces provide the following velocity and force profile:

Motor Dimensioning

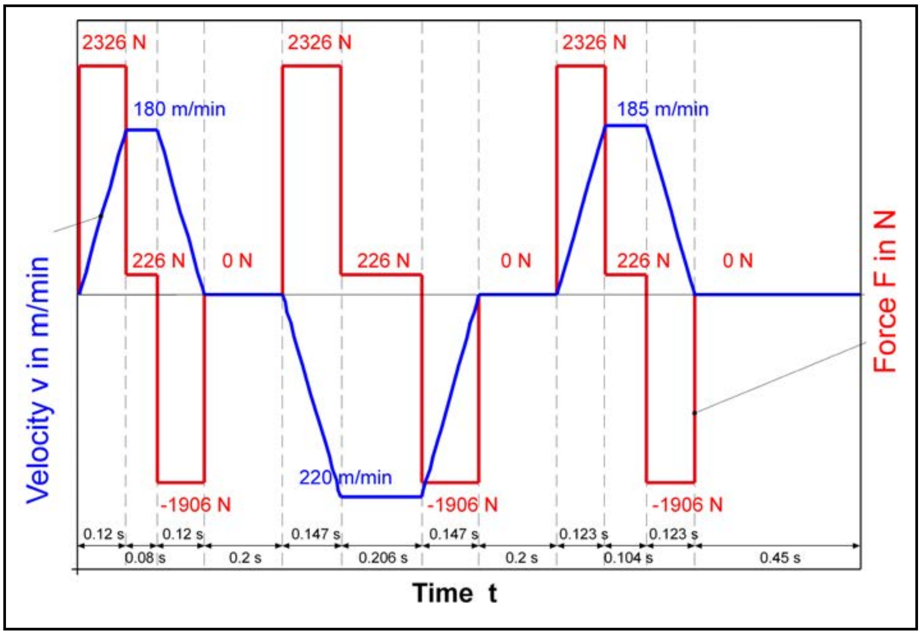


Fig. 10-39: Velocity and force profile of handling axis

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_{avgi} in m/min
1	0,120	2326	$F_i = F_{acc}+F_0$	90
2	0,080	226	$F_i = F_0$	180
3	0,120	-1906	$F_i = -F_{acc}+F_0$	90
4	0,200	0		0
5	0,147	2326	$F_i = F_{acc}+F_0$	110
6	0,206	226	$F_i = F_0$	220
7	0,147	-1906	$F_i = -F_{acc}+F_0$	110
8	0,2	0		0
9	0,123	2326	$F_i = F_{acc}+F_0$	92,5
10	0,104	226	$F_i = F_0$	185
11	0,123	-1906	$F_i = -F_{acc}+F_0$	92,5
12	0,45	0		0

Fig. 10-40: Force profile vs. time to determine the effective force

$$F_{eff} = \sqrt{\frac{\sum (F_i^2 \cdot t_i)}{t_{ges}}} \qquad v_{avg} = \frac{\sum v_{avgi} \cdot t_i}{t_{ges}}$$

$$F_{eff} = 1325\,N \qquad v_{avg} = 77.1\,m/min$$

Fig. 10-41: 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:

Motor: MLP140C-0170-FS-xxxx

Drive device: HMS01.1N-W150

Verification of mass and attractive force

The mass and attractive force of the selected primary part MLP140C-0170-FS corresponds to the estimated values. 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. 10-39), 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.

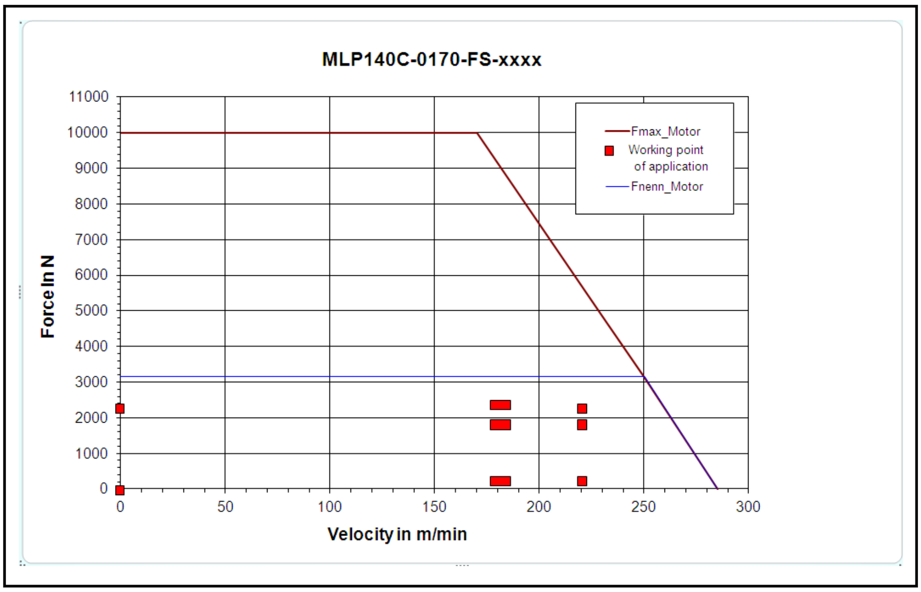


Fig. 10-42: Force-velocity diagram of handling axis (operating points and motor characteristic)

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.

Motor Dimensioning

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.

$$L_{sec\,ondary} \geq L_{total\ travel} + L_{primary}$$
$$L_{secondary} = 1300\ mm + 510\ mm$$
$$L_{secondary} = 1810\ mm$$

Fig.10-43: 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. 1800 mm) ausgewählt.

Power Calculation

$$P_{cm} = F_{eff} \cdot v_{avg}$$
$$P_{cm} = 1325\ N \cdot \frac{77.1\ m/min}{60}$$
$$P_{cm} = 1031\ W$$

Fig.10-44: Rated mechanical power

$$P_{ce} = \left(\frac{F_{eff}}{F_{n\_motor}}\right)^2 \cdot P_{vN}$$
$$P_{ce} = \left(\frac{1325\ N}{3150\ N}\right)^2 \cdot 2000\ W$$
$$P_{ce} = 354\ W$$

Fig.10-45: Electric continuous power loss

$$P_c = P_{cm} + P_{ce}$$
$$P_c = 1031\ W + 354\ W$$
$$P_c = 1385\ W$$

Fig.10-46: Total rated power

$$P_{maxm} = F_{max} \cdot v_{Fmax}$$
$$P_{maxm} = 2326\ N \cdot \frac{220\ m/min}{60}$$
$$P_{maxm} = 8529W$$

Fig. 10-47: Maximum output mechanical

Fig. 10-26 is used for determining the maximum electrical power loss. The ratio of required maximum force and maximum force of the motor is 2,326 N / 10,000 N = 0.23

Thus, Fig. 10-26 shows 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

$$P_{maxe} = 0.03 \cdot P_{max\ motor}$$
$$P_{maxe} = 0.03 \cdot 60.84\ kW$$
$$P_{maxe} = 1.83\ kW$$

Fig. 10-48: Maximum output electrical

$$P_{max} = P_{maxm} + P_{maxe}$$
$$P_{max} = 8.53\ kW + 1.83\ kW$$
$$P_{max} = 10.36\ kW$$

Fig. 10-49: Total maximum output

$$P_{co} = P_{ce} = 354\ W$$

Fig. 10-50: Cooling capacity

Fig. 10-28 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. 10-51: Regeneration energy

No.:	Braking time t_{bi}	Feed rate	Acceleration	Energy regeneration P_{Ri}
1	0.120 s	180 m/min	- 25 m/s²	1678 W
2	0.147 s	220 m/min	- 25 m/s²	2305 W
3	0.123 s	185 m/min	-25 m/s²	1767 W

Fig. 10-52: 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. 10-53: Average energy regeneration

Additional capacities for deactivation the axis upon a power failure

Additional DC bus capacities (capacitors) 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.

$$C_{add} = \frac{m_{ges} \cdot v_{max}}{U_{DCmax}^2 - U_{DCmin}^2} \cdot \left[3{,}5 \cdot \frac{F_{max\_motor}}{k_{iF}^2} \cdot R_{12} - v_{max} \cdot \left(\frac{F_R}{F_{max\_motor}} + 0.3\right)\right]$$

$$C_{add} = \frac{84\ \text{kg} \cdot 4.17\ \frac{\text{m}}{\text{s}}}{(540\ \text{V})^2 - (50\ \text{V})^2} \cdot \left[3{,}5 \cdot \frac{10000\ \text{N}}{\left(82\ \frac{\text{N}}{\text{A}}\right)^2} \cdot 1.2\ \Omega - 4.17\ \frac{\text{m}}{\text{s}} \cdot \left(\frac{226\ \text{N}}{10000\ \text{N}} + 0.3\right)\right]$$

$$C_{add} = 0.00594\ \text{F} = 5.9\ \text{mF}$$

Fig. 10-54: 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:

$$\eta_c = \frac{P_{cm}}{P_{cm} + P_{ce}} = \frac{1031\ \text{W}}{1031\ \text{W} + 354\ \text{W}}$$

$$\eta_c = 0.743$$

Fig. 10-55: 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. 10-56: Final overtemperature of the motor

Final overtemperature of the motor winding

$$\vartheta_{w} = \left(\frac{F_{eff}}{F_{n\_motor}}\right)^2 \cdot \vartheta_{wg}$$
$$\vartheta_{w} = \left(\frac{1325\ N}{3150\ N}\right)^2 \cdot 130K$$
$$\vartheta_{w} = 55\ K$$

Fig. 10-57: Final overtemperature of the motor winding

Absolute final temperature of the motor winding

$$\vartheta_{wabs} = \vartheta_{w} + \vartheta_{coolant}$$
$$\vartheta_{wabs} = 55\ K + 25\ K$$
$$\vartheta_{wabs} = 80\ °C$$

Fig. 10-58: Absolute final temperature of the motor winding

Reaching the final temperature

The thermal time constant of the selected motor is T_{th} = 6 min. 98% of the final temperature is reached after approximately 4 thermal time constants (i.e. after 24 minutes).

☞ Additional explanations of the thermal behavior of linear motors can be found in chapter 9.6.2 "Thermal Behavior of Linear Motors" on page 144.

10.6.2 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	Rate
Acceleration and declaration	10 %
Rapid traverse	20 %
Machining process	30 %
Standstill with machining	20 %
Standstill without machining	20 %
Total:	**100 %**

Fig. 10-59: Percentage of individual machining processes and movements

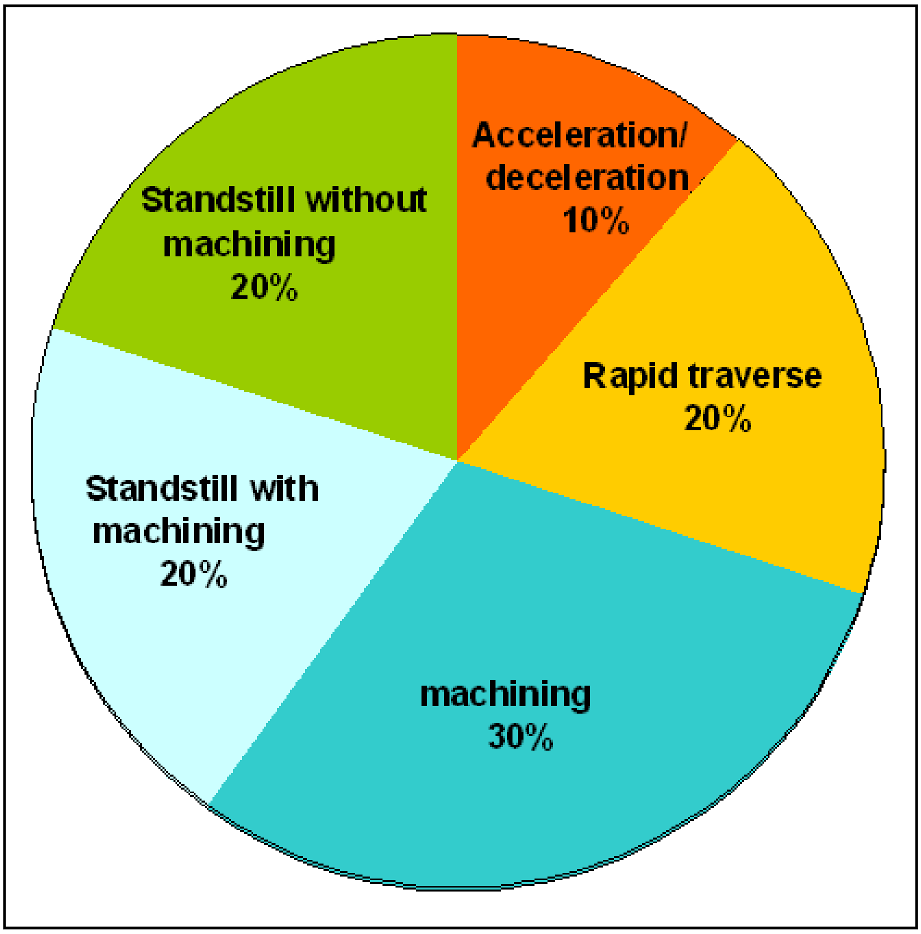


Fig. 10-60: Graphical presentation of the individual operating phases

Calculation

$$F_{acc} = m_{ges} \cdot a$$
$$F_{acc} = 580\,kg \cdot 15\,m/s^2$$
$$F_{acc} = 8700\,N$$

Fig. 10-61: Acceleration force

$$F_{max} = F_{acc} + F_0$$
$$F_{max} = 8700\ N + 600\ N$$
$$F_{max} = 9300\,N$$

Fig. 10-62: 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 %	8,700 N	$F_i = F_{acc} \pm F_0$	60 m/min
Rapid traverse	20 %	600 N	$F_i = F_0$	120 m/min
Machining process	30 %	1,800 N	$F_i = F_P + F_0$	15 m/min
Standstill with machining	20 %	1,200 N	$F_i = F_P$	0 m/min
Standstill without machining	20 %	0 N		0 m/min

Fig. 10-63: Percentage of individual machining processes and movements

$$F_{eff} = \sqrt{\sum \left(F_i^2 \cdot \frac{ED_i}{100}\right)} \qquad v_{avg} = \sum \left(v_{avgi} \cdot \frac{ED_i}{100}\right)$$

$$F_{eff} = 2983\ N \qquad v_{avg} = 34.5\ m/min$$

Fig. 10-64: 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 F_{max_motor}: 10,000 N F_{n_motor}: 3,150 N $v_{Fmax\ 750V}$:170 m/min $v_{NENN\ 750V}$: 250 m/min
Secondary part segments	MLS140A-3A-xxxx-NNNN 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 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.10-65: Electric continuous 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.10-66: Required coolant flow

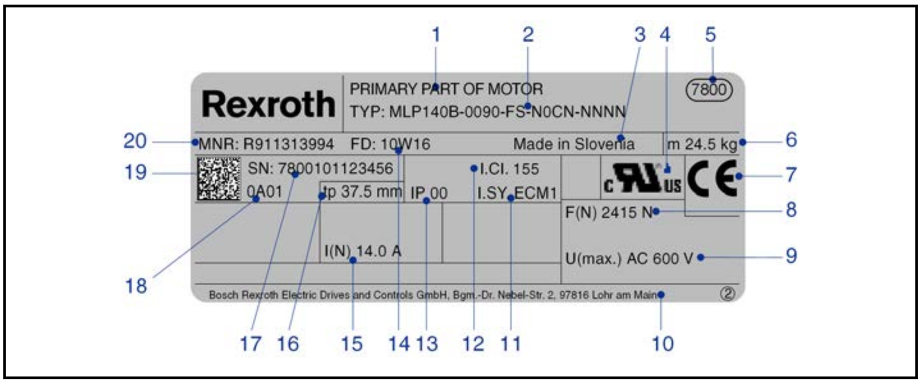
☞ The way of determining the drive power and other more detailed data are not discussed within the scope of this example.

11 Handling, Transport and Storage

11.1 Identification of the Motor Components

11.1.1 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:



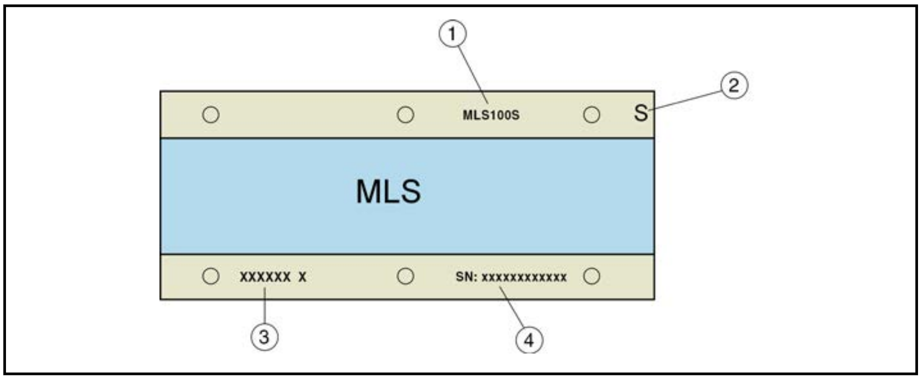
1	Motor type
2	Type designation
3	Designation of origin
4	UL sign
5	Factory number
6	Mass of primary part
7	CE sign
8	Rated power
9	Maximum input voltage
10	Company address
11	Insulation system
12	Thermal temperature class
13	Protection class by housing
14	Production date
15	Rated current
16	Pole graduation
17	Serial number
18	Revision state
19	Rexroth bar code
20	Part number

Fig. 11-1: Type plate primary part

11.1.2 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.

Handling, Transport and Storage



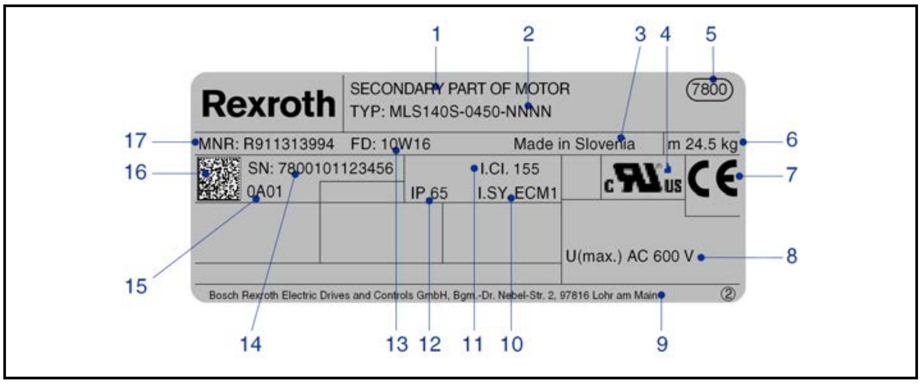
①	Type designation
②	Pole designation ”S” (for south pole)
③	Internal designation
④	Serial number

Fig. 11-2: 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

Rating Plate

The type plate of the secondary part contains the following data:



1	Motor type
2	Type designation
3	Designation of origin
4	UL mark
5	Factory number
6	Secondary part mass
7	CE sign
8	Maximum input voltage
9	Company address
10	Insulation system
11	Thermal temperature class
12	Protection class by housing
13	Production date
14	Serial number
15	Revision state
16	Rexroth bar code
17	Part number

Fig. 11-3: Type plate secondary part

11.2 Delivery Status and Packaging

11.2.1 Primary Parts

The primary parts are separately packed in a wooden box. To identify the primary part, a type designation exist on the packaging.

11.2.2 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:

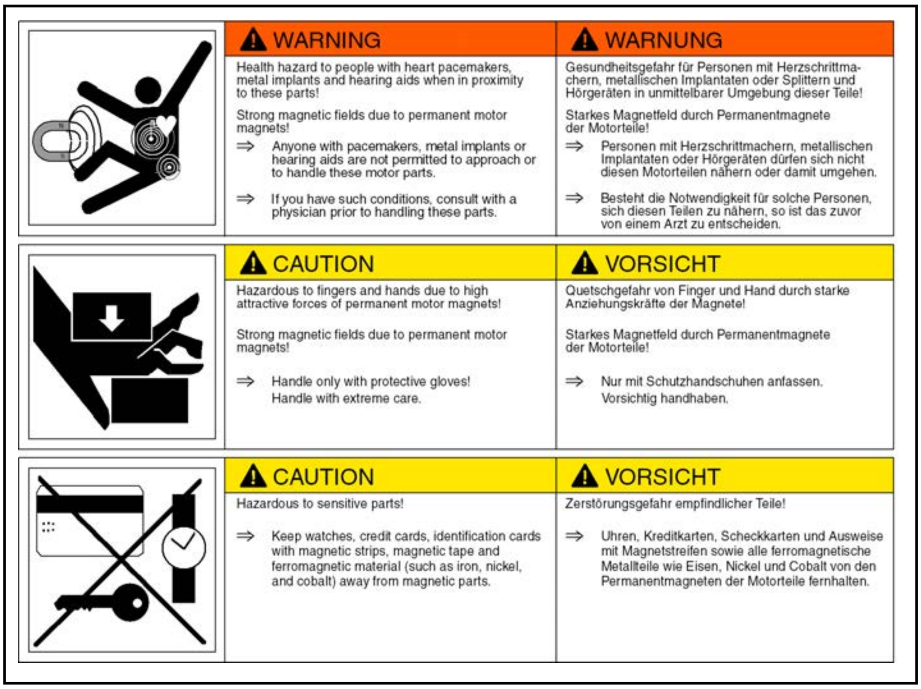


Fig. 11-4: Warning label on the packaging of MLS secondary parts

☞ The self-sticking warning label (sizes approx. 110 mm x 150 mm) can be ordered from Rexroth (MNR R911278745).

11.3 Transport and Storage

11.3.1 Transport Instructions

Transport our products only in their original package. Also observe specific ambient factors to protect the products from transport damage.

Based on DIN EN 60721-3-2, the tables below specify classifications and limit values which are allowed for our products while they are transported by land, sea or air. Observe the detailed description of the classifications to take all of the factors which are specified in the particular class into account.

Allowed classes of ambient conditions during transport acc. to DIN EN 60721-3-2

Classification type	Allowed class
Classification of climatic ambient conditions	2K2
Classification of biological ambient conditions	2B1
Classification of chemically active materials	2C2
Classification of mechanically active materials	2S2
Classification of mechanical ambient conditions	2M1

Fig.11-5: Allowed classes of ambient conditions during transport

For the sake of clarity, a few essential environmental factors of the aforementioned classifications are presented below. Unless otherwise specified, the values given are the values of the particular class. However, Bosch Rexroth reserves the right to adjust these values at any time based on future experiences or changed ambient factors.

Allowed transport conditions

Environmental factor	Symbol	Unit	Value
Temperature	T_T	°C	-20 ... +80 1)
Air humidity (relative air humidity, not combinable with quick temperature change)	φ	%	75 (at +30 °C)
Occurence of salt mist			Not permitted 1)

1) Differs from DIN EN 60721-3-2

Fig.11-6: Allowed transport conditions

☞ Before transport, empty the liquid coolant from the liquid-cooled motors to avoid frost damage.

To lift the motor out of the transport crate or to install it into the machine, use the lifting eye bolts at the motor.

The ring screws must meet the requirements of DIN 580. Before each transport, ensure that the lifting eye bolts are screwed down fully to the stop face and that your selected lifting equipment and lifting method will not overload the lifting eye bolts.

☞ Please note DIN 580 standard on the transport of motors. Non-observance of the information in this standard may cause overload of the lifting eye bolts and result in injury to persons or damage to products.

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.

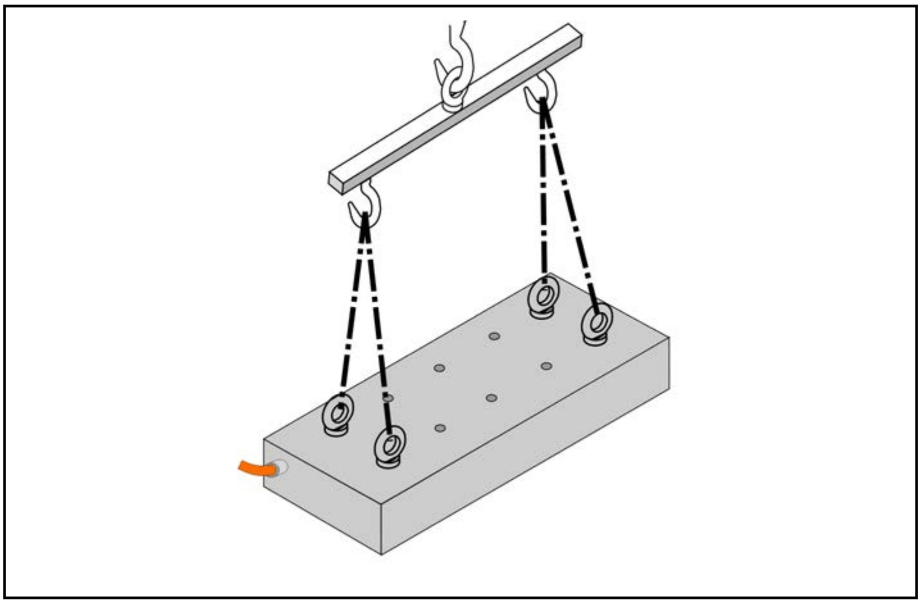


Fig.11-7: Transport of a primary part (example)

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. 11-4) 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.

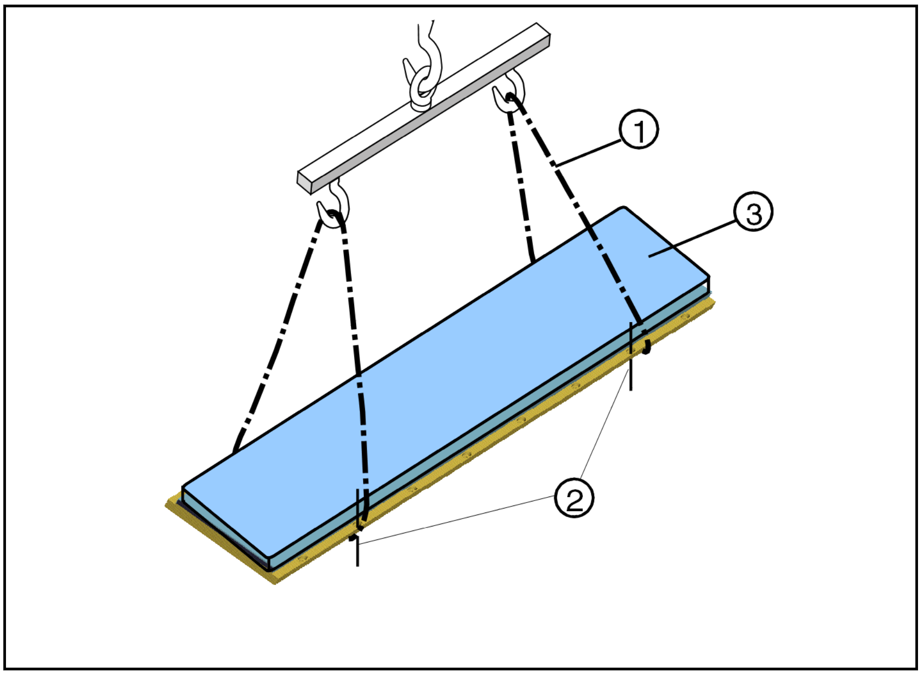
We recommend to use lifting belts to transport the secondary part.

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. 11-8). 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. 11-8: 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.

Instructions on transport by air

If motor components with permanent magnets are dispatched by air, IATA's (International Air Transport Association) DGR - Dangerous Goods Regulations must be observed for hazardous materials of class 9 which also include magnetized materials and objects. This involves, for example:

- Secondary parts of synchronous linear motors
- Rotors of synchronous kit motors
- Rotors of synchronous housing motors (if these are dispatched as motor component, i.e. separate from the stator or motor housing, in service cases)

Please also observe the information provided in "Air freight (IATA953)" on page 167. For details on the maximum allowed magnetic field strengths as well as information on measurement methods for these magnetic field strengths, please refer to the current IATA DGR.

11.3.2 Storage Instructions

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.

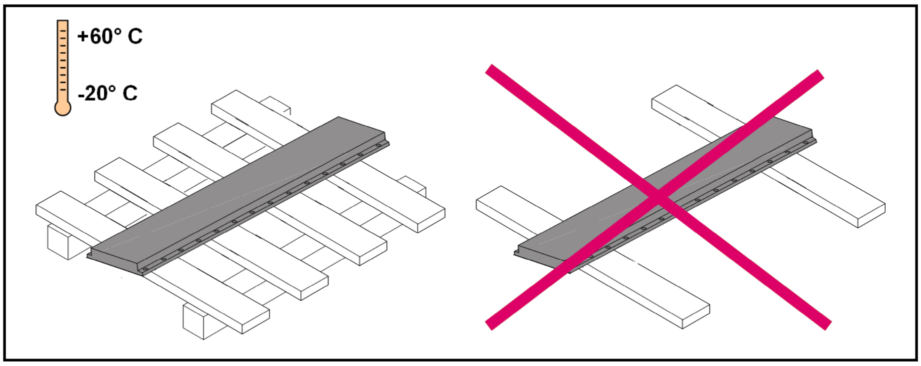


Fig. 11-9: Storage of linear motor components

⚠ 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 .

⇒ Short-term storage during installation acc. to Fig. 11-9

⇒ 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.

Generally, Bosch Rexroth recommends to store all components until they are actually installed in the machine as follows:

- In their original package
- At a dry and dustfree location
- At room temperature
- Free from vibrations
- Protected against light or direct insolation

On delivery, protective sleeves and covers may be attached to our motors. They must remain on the motor for transport and storage. Do not remove these parts until shortly before assembly.

Based on DIN EN 60721-3-1, the tables below specify classifications and limit values which are allowed for our products while they are stored. Observe the detailed description of the classifications to take all of the factors which are specified in the particular classification into account.

Allowed classes of ambient conditions during storage acc. to DIN EN 60721-3-1

Classification type	Class
Classification of climatic ambient conditions	1K2
Classification of biological ambient conditions	1B1
Classification of chemically active materials	1C2
Classification of mechanically active materials	1S1
Classification of mechanical ambient conditions	1M2

Fig. 11-10: Allowed classes of ambient conditions during storage

For the sake of clarity, a few essential environmental factors of the aforementioned classifications are presented below. Unless otherwise specified, the values given are the values of the particular class. However, Bosch Rexroth reserves the right to adjust these values at any time based on future experiences or changed ambient factors.

Allowed classes of ambient conditions during storage acc. to DIN EN 60721-3-1

Environmental factor	Symbol	Unit	Value
Air temperature	T_L	°C	-20 ... +60 1)
Relative air humidity	φ	%	5 ... 95
Absolute air humidity	ρw	g/m³	1 ... 29
Condensation	-	-	Not allowed
Ice formation/freezing	-	-	Not allowed
Direct solar radiation	-	-	Not allowed 1)
Occurence of salt mist	-	-	Not allowed 1)

1) Differs from DIN EN 60721-3-1

Fig.11-11: Allowed storage conditions

☞ Before re-storage, empty the liquid coolant from the liquid-cooled motors to avoid frost damage.

Irrespective of the storage duration - which can exceed the warranty period of our products - the function remains maintained provided additional measures are taken into account and carried out during commissioning. However, this does not involve any additional warranty claims.

Motors

Bearing time / months			Measures for commissioning
> 1	> 12	> 60	
■	■	■	Visual inspection of all parts to be damage-free
	■	■	Check the electric contacts to verify that they are free from corrosion
	■	■	Measure insulation resistance. Dry the winding at a value of < 1kOhm per volt rated voltage.

Fig.11-12: Measures before commissioning motors that have been stored over a prolonged period of time

Cables and Connectors

Bearing time / months			Measures for commissioning
> 1	> 12	> 60	
■	■	■	Visual inspection of all parts to be damage-free
	■	■	Check the electric contacts to verify that they are free from corrosion
		■	Visually inspect the cable jacket. Do not use the cable if you detect any abnormalities (squeezed or kinked spots, color deviations, ...).

Fig. 11-13: Measure before commissioning cables and connectors that have been stored over a prolonged period of time

11.4 Checking the Motor Components

11.4.1 Factory Checks of the Motor Components

Electrical inspections

The Bosch Rexroth linear motors undergo the following electrical checks at the factory:

- High voltage test according to DIN EN 60034-1
- Insulation resistance test acc. to DIN 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

11.4.2 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!

12 Assembly

12.1 Basic Precondition

Basic precondition for mounting the IndraDyn L components is the keeping of the following points:

- Observation of the necessary installation sizes (see Fig. 5-1 on page 75)
- 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.

Screwlock

All screwed connections must be secured against potential impacts and vibrations during operation of the machine. A suitable and field-tested screw lock for all metal thread connections is, e.g., Loctite 243.

Loctite 243 is a liquid screw lock (medium-hard) and is applied to the parts to be mounted immediately prior to assembly. For detailed information on the proper handling and processing, please refer to the manufacturer's data sheets under http://www.loctite.de. The manufacturer's homepage also provides information on hardening accelerators or other screw locks.

12.2 General Procedure at Mounting of the Motor Components

12.2.1 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.

12.2.2 Installation at a Path with Several Secondary Parts

At an existing path, installation with several secondary parts can be done as described in Fig. 5-1 on page 75. 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.

Assembly

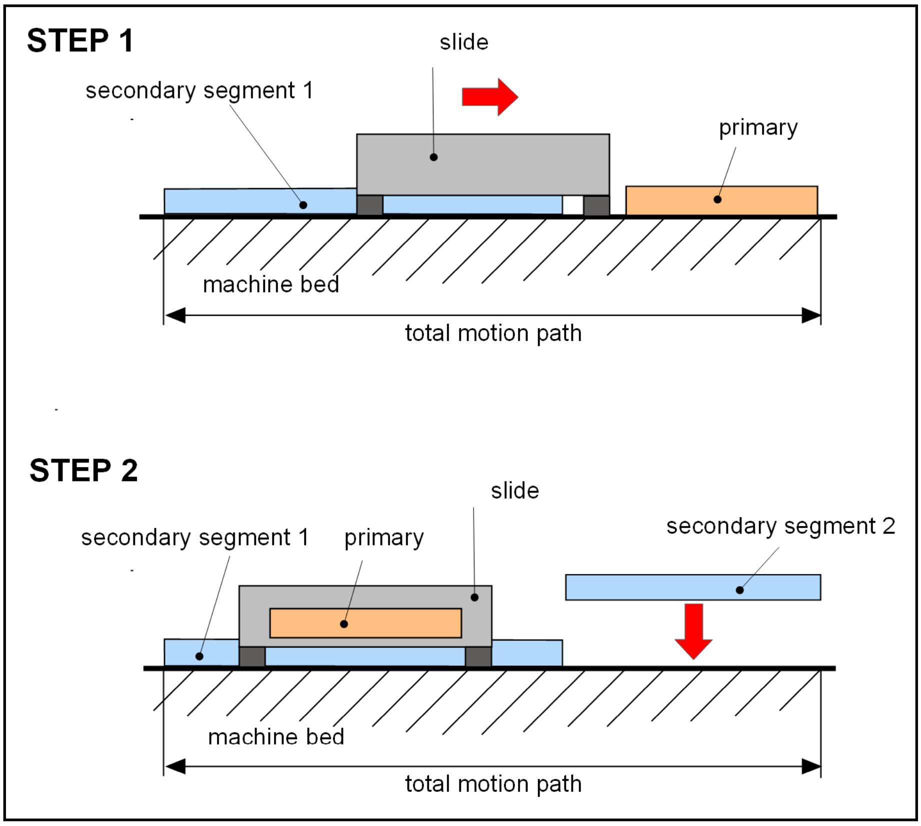


Fig. 12-1: Installation of linar motor components at a path with several secondary parts

⚠ CAUTION **Uncontrolled movement of the slide! Danger of crushing or injury!**

⇒ Safety against uncontrolled movements by partial covering of primary and secondary parts (force in traverse direction).

12.2.3 Installation at a Path with One Secondary Part

At a path with one secondary part, the primary part can 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

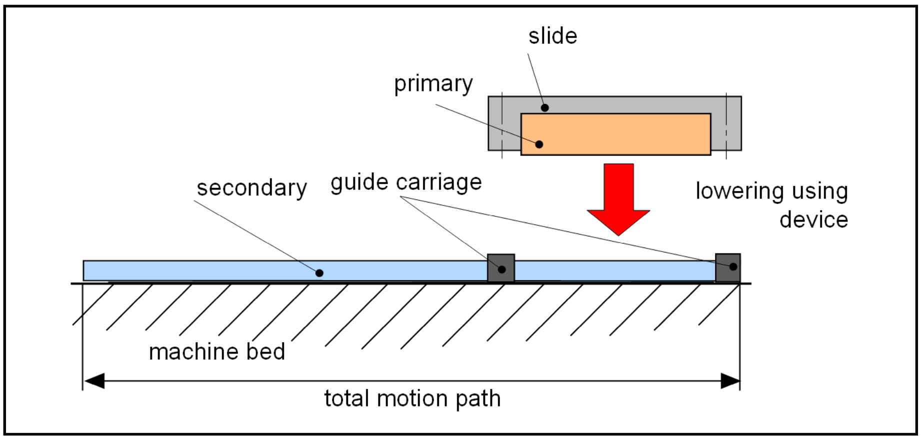


Fig. 12-2: Installation of linear motor components at a path with several secondary parts

☞ 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 on page 139.

⇒ 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 mm

The tightening of the fastening screws for the primary part has to be made as described in chapterChapter 12.4 on page 238.

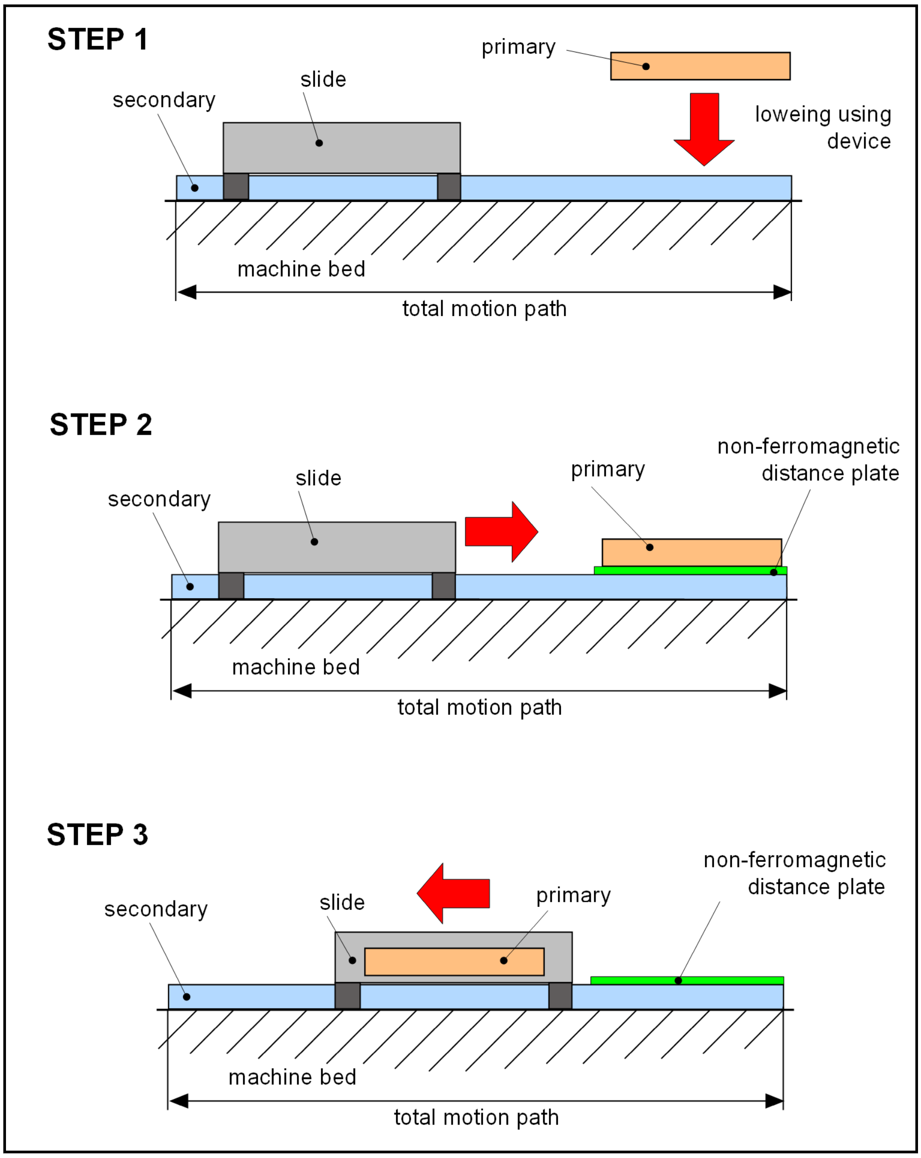


Fig. 12-3: Installation of the linear motor components at whole secondary part over the entire traverse path

12.3 Installation of Secondary Part at a Path with one Separate Secondary Part

⚠ 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 specified tightening torque (see Fig. 12-4 on page 235) and provide them with screw locking device.

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:

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. 12-4: 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. 9-42 on page 147).

☞

- 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.

Spanned secondary part

⚠ WARNING

Malefunction and / or uncontrolled movement of the motor result in danger of damage or risk of injury!

⇒ Correct sequence of 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.

Assembly

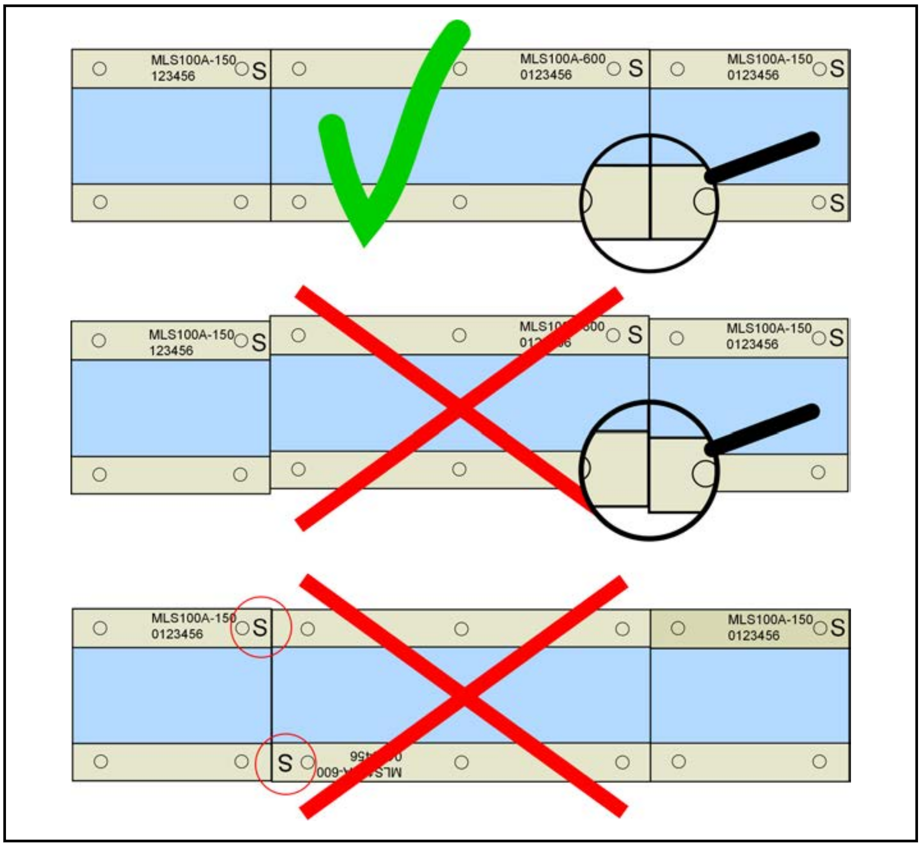


Fig. 12-5: Arrangement of several secondary parts

⚠ WARNING **Risk of injury or damage by attractive force or repulsive force when arranging the secondary part segments!**

⇒ Secure the motor 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.

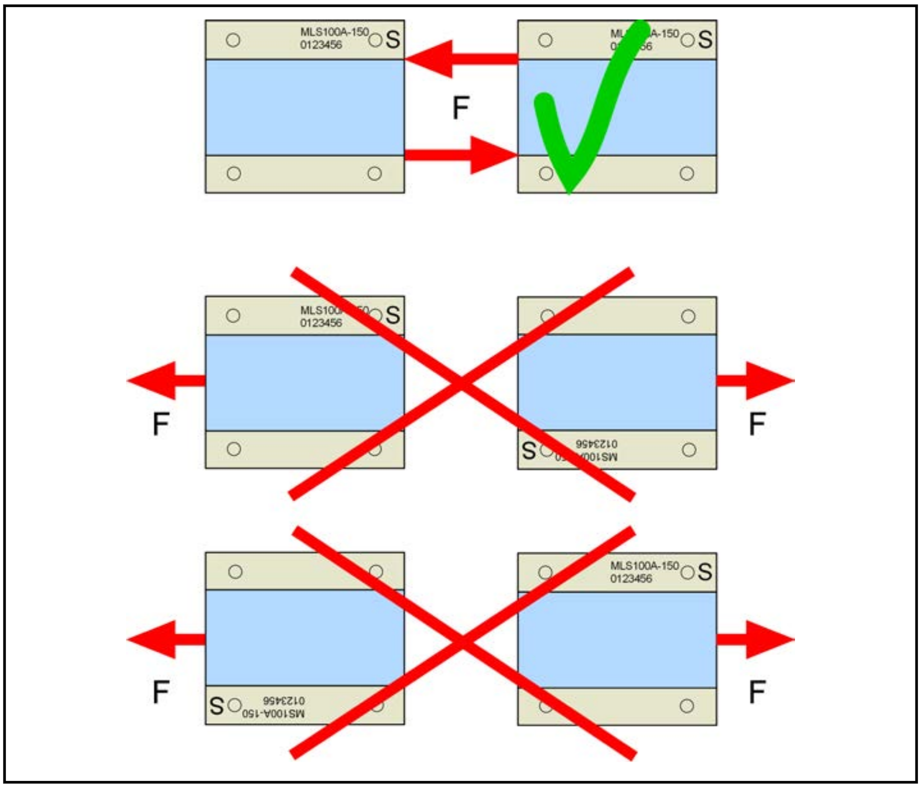


Fig.12-6: Attractive or repulsive force when arranging the secondary part segments

12.4 Installation of the Primary Part

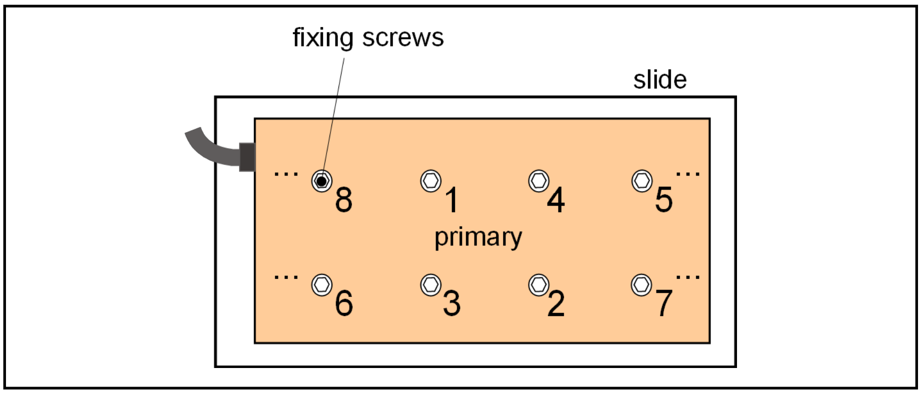


Fig. 12-7: Order of tightening the fastening screws of the primary part

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. Clean or prepare threaded holes and screws for assembly.
2. Secure all screwed connections with screw connection, e.g. Loctite 243.
3. Fasten the primary part with screws 1, 2, 3...x until the primary part lies on the slide.
4. 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 EN ISO 4762)	8.8	10 Nm
		10.9	15 Nm

Fig. 12-8: Nominal tightening torque for the fastening screws of the primary parts

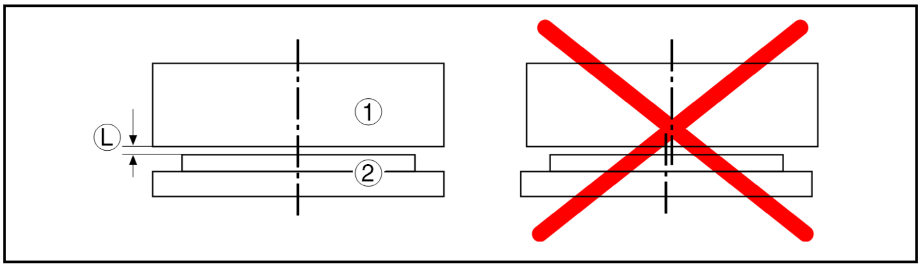
☞ The effect of liquid screw locking is damaged due to loosening or re-tightening of the screws (e.g. due to torque check) and must be carried out again. Observe the instructions of the adhesive manufacturer.

12.5 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 on page 76).

As a small tolerance exists within the holes of the screw connections, the parts must be averaged and arranged according to Fig. 12-5 before the screws are finally tightened.



①	Primary part
②	Secondary part
(L)	Air gap

Fig. 12-9: 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.

12.6 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. 12-10) 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 ports are provided for coolant port connections with axial seal.

Bosch Rexroth therefore recommends to use screw connections which already contain an O-ring for sealing the screw connection in axial direction.

For example, seals consisting of hemp, teflon tape or cone-shaped screw connections are not considered to be suitable because this type of seal may stress the connection thread on the motor to an unreasonably high extent and/or damage it permanently.

☞ The machine manufacturer is responsible for ensuring that the coolant port is tight and for verifying and accepting this tightness after the motor has been installed.

Moreover, the maintenance schedule of the machine should provide for a regular check of the proper state of the cooling port.

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	Screw-in depth
Standard encapsulation	G1/4	max. 30 Nm	max. 12 mm
Thermal encapsulation			

Fig.12-10: Connection liquid cooling

13 Commissioning, Operation and Maintenance

13.1 General Information for Startup of IndraDyn L Motors

The startup of linear motors is different to the rotary servo motors. The differences are described in this chapter.

☞ Refer to the functional description of the drive controller for more detailed information.

The following points have to be especially noticed when startup synchronous-linear motors.

Parameters

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, kit motors do not feature any data memory to provide motor parameters, standard controller settings, etc. All parameters must be manually entered or loaded to the drive during commissioning. The start-up-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 rotary servo drives can be, for example, a 10-fold higher kv-factor adjusted. Precondition therefore is an appropriate machine construction (see Chapter 9.3 on page 130).

Moving Masses

At controlled rotary 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 referred to as pole position detection or commutation adjustment. This means that the commutation adjustment 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.

13.2 General Requirements

13.2.1 General Information

The following requirements must be met to ensure successful commissioning:

- Compliance with safety-related guidelines and instructions
- Check of electrical and mechanical components for reliable functioning
- Availability and provision of required tools
- Adherence to the commissioning procedure described below

13.2.2 Checking All Electrical and Mechanical Components

Check all electrical and mechanical components prior to commissioning and pay particular attention to the following issues:

☞

- Ensure safety for man and machine
- Properly install the motor
- Properly establish the power connection of the motor
- Correct connection of the length measuring system
- Ensure proper function of existing safety limit switches, door switches, etc.
- Ensure proper function of the emergency stop circuit and emergency stop.
- Ensure proper and complete machine construction (mechanical installation)
- Availability and function of suitable end-of-stroke damper.
- Ensure proper connection and function of the motor cooling system
- Ensure proper connection and function of drive controller and control unit

⚠ WARNING **Danger to life, heavy injury or damage by failure or malfunction of mechanical or electrical components!**

⇒ Troubleshooting at mechanical or electrical components before continue with the start-up.

13.2.3 Tools

DriveTop commissioning software The motors can be commissioned either directly via an NC terminal or via special commissioning software. The DriveTop commissioning software allows menu-driven, custom-designed and motor-specific parameterization and optimization.

PC At start-up with DriveTop requires a commercial Windows PC.

Commissioning via NC Commissioning via the NC control unit requires access to all drive parameters and functionalities.

Oscilloscope An oscilloscope is required for drive optimization. This oscilloscope serves to display the signals which can be output via the adjustable analog outputs 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.

13.3 General Start-Up Procedure

In the following flow-chart is the general start-up procedure at synchronous linear motors MLF shown. The individual items are explained in more detail in the chapters following thereafter.

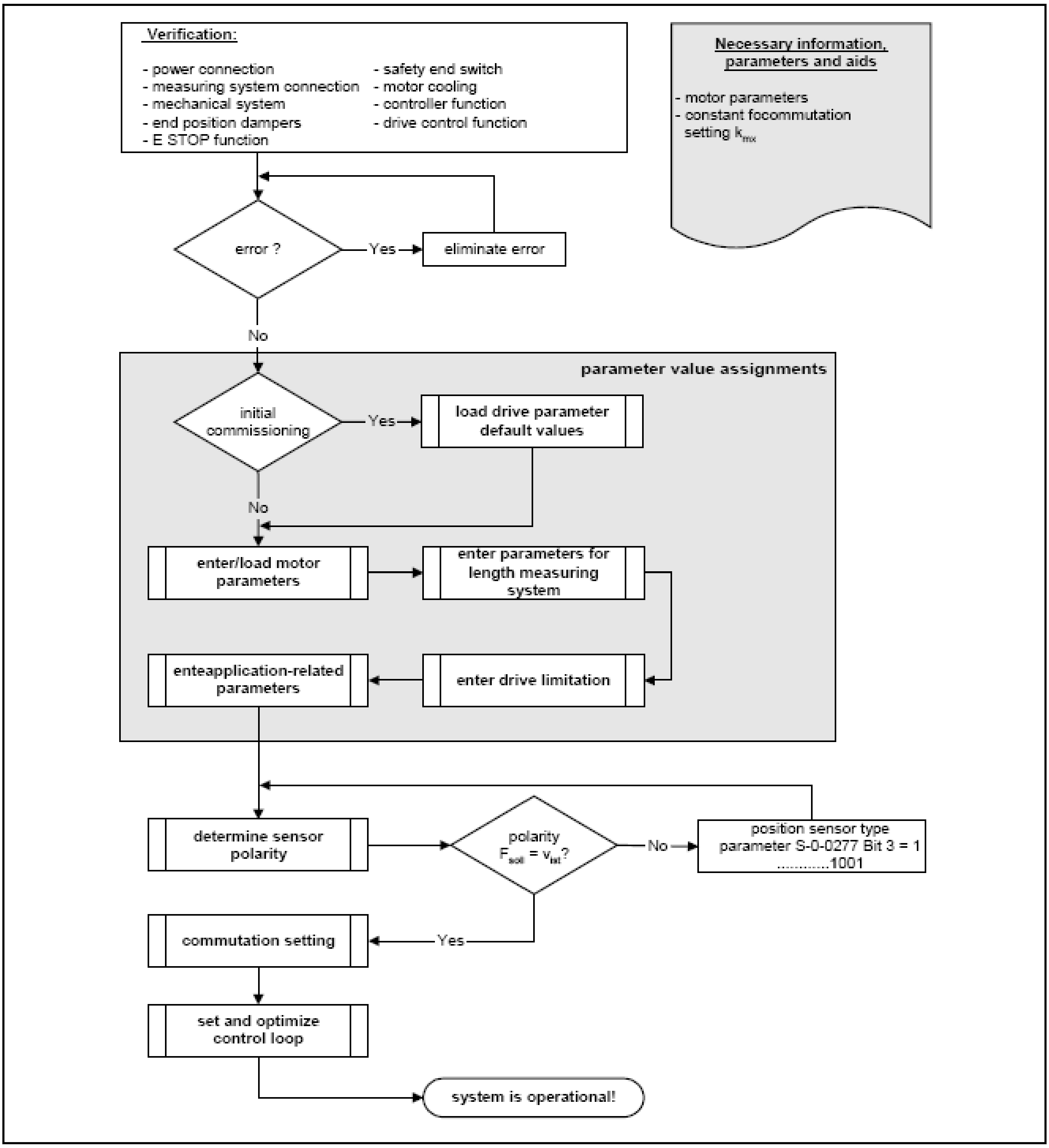


Fig.13-1: General start-up procedure at synchronous linear motors

13.4 Parameterization

13.4.1 General Information

DriveTop allows entering or editing certain parameters and executing commands during commissioning by means of menu-driven dialogs and list representations or, optionally, via the control terminal.

13.4.2 Entering Motor Parameters

☞ Motor parameters are specified by Rexroth and may not be changed by the user. Commissioning is not possible, if these parameters are not available. In this case, please contact your Rexroth Sales and Service Facility.

⚠ WARNING

Activation of the motor immediately after motor parameter input may result in injury and mechanical damage! The motor is not yet ready for operation after the motor parameters have been entered!

⇒ Enter the parameters for the linear scale.

⇒ Check and adjust the measuring system polarity.

⇒ Adjust the commutation

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.

13.4.3 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-0-0106	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.13-2: 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.

13.4.4 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 9.6.5 on page151 about operation of an IndraDyn L motor without liquid cooling.

13.4.5 Entering Length Measuring System Parameter

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	2
Absolute encoder with ENDAT interface	8
Incremental encoder with Hall sensor	14 or 15 (depending from hardware configuration)

Fig. 13-3: Defining the encoder type

☞ Detailed information can be found in the project planning manual of the used drive controller and/or firmware

- Rexroth IndraDrive MPx-xx Parameter description, MNR R911328650
- Rexroth IndraDrive MPx-xx Parameter description, MNR R911297317
- Rexroth IndraDrive Firmware MPx-xx Funktionsbeschreibung, MNR R911328670
- Rexroth IndraDrive MPx-xx Parameter description, MNR R911326767

Signal period

Linear scale for linear motors generate and interpret **sinusoid signals**. The signal period must be entered in parameter S-0-0116, Resolution of feedback 1.

Please observe the details of the measuring system manufacturer regarding resolution of encoder signals.

13.4.6 Entering Drive Limitations and Application-related Parameters

Drive limitations

The possible selectable drive limitations include:

- Current limitation
- Force limitation
- Velocity limitations
- Travel range limitations

Application-related parameters

Application-related drive parameters include, for example, parameterization of the drive fault reaction.

☞ Detailed information can be found in the project planning manual of the used drive controller and/or firmware

13.5 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!

⇒ Secure the motor 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.

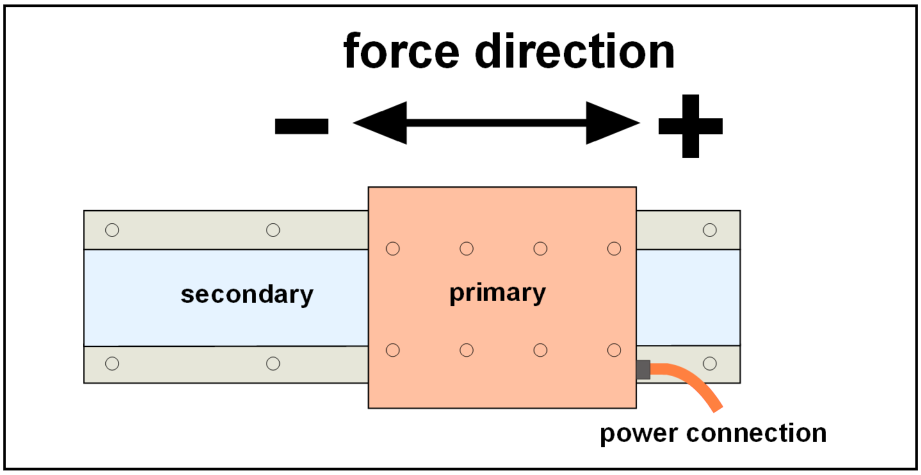


Fig. 13-4: Effective direction of motor force

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:

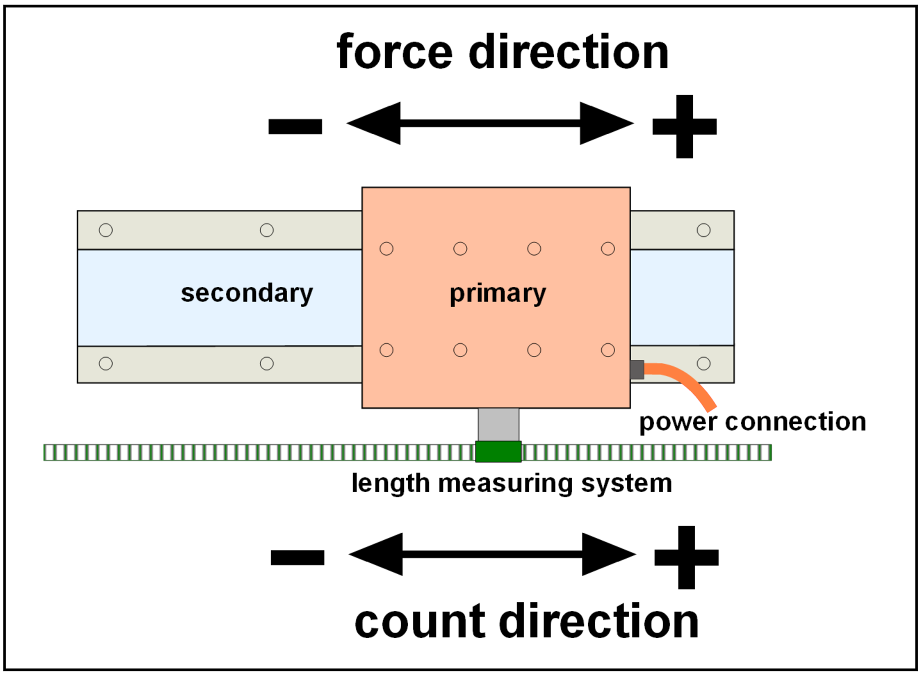


Fig. 13-5: Effective direction motor force = linear scale count direction

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☞ 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, Torque/force polarity parameter 0000000000000000

S-0-0043, Velocity polarity parameter 0000000000000000

S-0-0055, Position polarities 0000000000000000

The process-related axis count direction is set as required **after** sensor polarity and commutation have been set.

13.6 Commutation Adjustment

13.6.1 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 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.

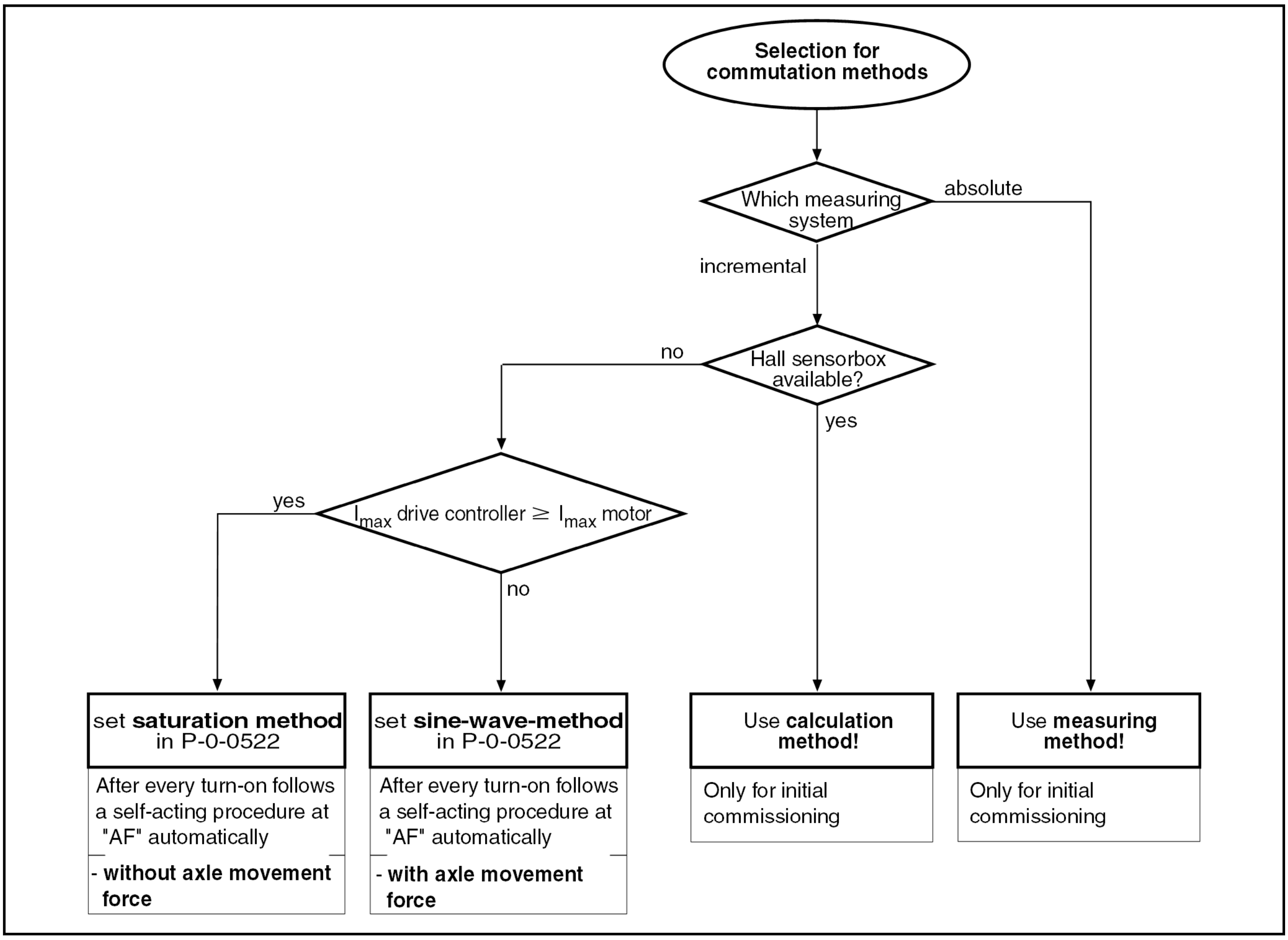

Fig. 13-6: Commutation adjustment method for synchronous linear motors

☞ Commutation adjustment must always be performed in the following cases:

⇒ Initial start-up

⇒ After the mechanical attachment of the length measuring system has been modified

⇒ Replacement of the linear scale

⇒ Modification of the mechanical attachment of the primary and/or secondary part

☞ Observe the following requirements for commutation adjustment:

⇒ Effective direction motor force = linear scale count direction

⇒ Ensure correct motor and encoder parameterization

⇒ Follow the adjustment procedures described

⇒ Ensure reasonable parameterization of the current and velocity control loops

⇒ Correctly connect the motor power cable

⇒ Ensure protection against uncontrolled movements

⚠ DANGER **Errors in commutation adjustment may result in malfunctions and/or uncontrolled movements of the motor!**

Do the commutation adjustment very carefully and observe the detailled notes in chapter Commutation Adjustment of the functional description Firmware for Drive Controllers (DOK-INDRV*-MP*-08VRS**-..., MNR R911332643)and both prementioned notes.

Motor connection

The individual phases of the motor power connection must be assigned correctly. Also refer toChapter 8 on page 113.

Parameter verification

To ensure a correct commutation adjustment, the following parameters should be checked again:

Identity number	Description	Description / function
S-0-0085	Torque/force polarity parameter	See parameter description to Rexroth IndraDrive Drive Controllers (DOK-INDRV*-GEN-**VRS**-PA) with MNR R911297317.
S-0-0043	Velocity polarity parameter	
S-0-0055	Position polarities	
P-0-4014	Type of construction of motor	
P-0-0018	Number of pole pairs/pole pair distance	
S-0-0116	S-0-0016, Feedback 1 Resolution	
P-0-0522	Control word for commutation setting	

Fig. 13-7: Parameters that must be checked prior to commutation adjustment

13.6.2 Saturation Procedure (preferred Procedure for Commutation of Synchronous Linear Motors)

Saturation procedure is the preferred procedure to commutate the synchronous linear motors.

You will find detailed notes about saturation procedure in chapter "Commutation Adjustment" of firmware description DOK-INDRV*-MP*-08VRS**-..., MNR R911332643.

13.6.3 Sinusoidal Procedure

This procedure is applied if the saturation procedure cannot be used.

You will find detailed notes about sinusoidal procedure in chapter "Commutation Adjustment" of firmware description DOK-INDRV*-MP*-08VRS**-..., MNR R911332643.

13.6.4 Notes on Possibility of Subsequent Optimization of Commutation Offset

The procedure of subsequent optimization can be applied at sinusoidal procedure and saturation procedure. Prerequisites is that the axis must be free movable and not be locked.

We recommend, the determined value for commutation offset to be re-optimized. This can automatically be done by activation of "C5600 Command Subsequent optimization of commutation offset".

You will find detailed notes about subsequent optimization procedure in chapter "Commutation Adjustment" of firmware description DOK-INDRV*-MP*-08VRS**-..., MNR R911332643.

13.6.5 Calculation Procedure in Connection with Hall Sensor Box SHL

Calculation procedure is used for incremental measuring systems and use of Hall sensor box (distance measure, currentless → only possible for Rexroth linear kit motors). Please note the functional description about Hall sensor boxes SHL02.1 (DOK-SUPPL*-SHL********-FK) with material number R911306588.

You will find detailed notes about calculation procedure in chapter "Commutation Adjustment" of firmware description DOK-INDRV*-MP*-08VRS**-..., MNR R911332642.

13.6.6 Measuring Procedure: 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.

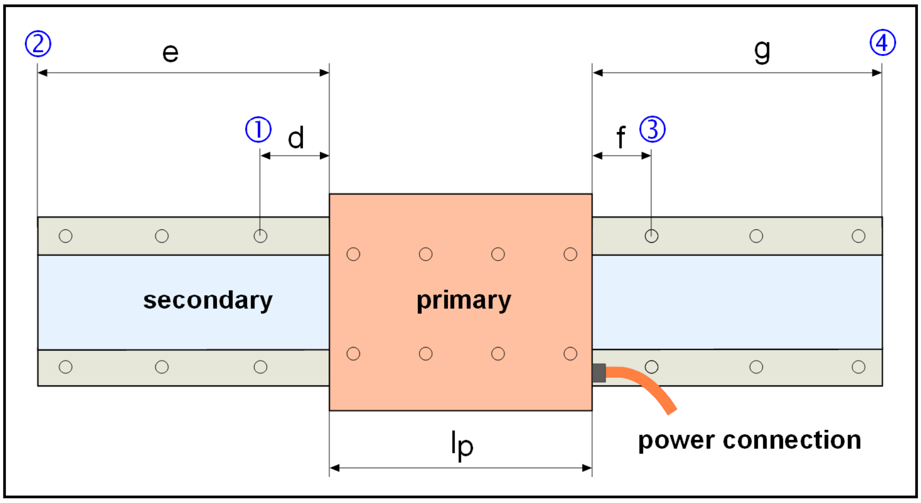

Fig. 13-8: Measuring the relative position between primary and secondary part

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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. 13-8, distance d, e, f or g, depending on accessibility), and a motor-related constant k_{mx} (Fig. 13-9 and Fig. 13-11).

Reference point 1: $$P-0-0523 = d - k_{mx}$$

Reference point 2: $$P-0-0523 = e - k_{mx} - 37.5\ mm$$

Reference point 3: $$P-0-0523 = -f - l_p - k_{mx}$$

Reference point 4: $$P-0-0523 = 37.5\ mm - g - l_p - k_{mx}$$

P-0-0523	Commutation adjustment measured value in mm
d	Relative position 1 in mm (Fig. 13-8)
n	Relative position 5.08 cm mm (Fig. 13-8)
f	Relative position 7.62 cm mm (Fig. 13-8)
g	Relative position 10.16 cm mm (Fig. 13-8)
k_{mx}	Motor constant for commutation adjustment in mm
l_P	Length of primary part in mm

Fig. 13-9: Calculation of P-0-0523, commutation adjustment measured value

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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:

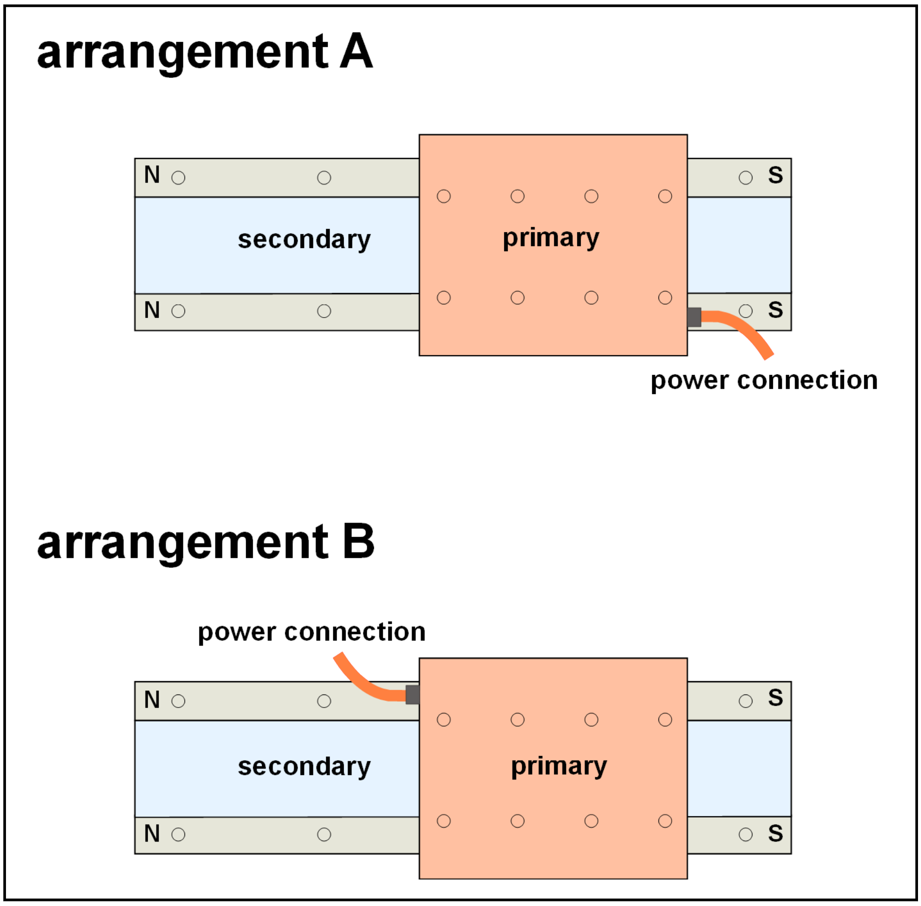

Fig. 13-10: Possible arrangements between primary and secondary part

	Arrangement A k_{mx} in mm	Arrangement B k_{mx} in mm
Standard encapsulationframe sizes 040 ... 300	68	105,5
Thermal encapsulation Size 040 ... 300	65	102,5

Fig. 13-11: Motor constants for commutation adjustment kmx

Example 1, reference ① (see Fig. 13-8):

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. 13-8):

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 ① (see Fig. 13-8):

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.

☞ If the drive is in command start "AB" (drive ready for operation), the commuation offset with the selected procedure (saturation or sinuisoidal procedure) is determined for automatic commutation.

The command must subsequently be cleared.

13.7 Setting and Optimizing the Control Loop

13.7.1 General Procedure

The control loop settings in a digital drive controller have an essential importance for the properties of the servo axis. The control loop structure consists of a cascaded position, velocity and current controller. Which of the controllers is active is defined by the operation mode.

☞ 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.

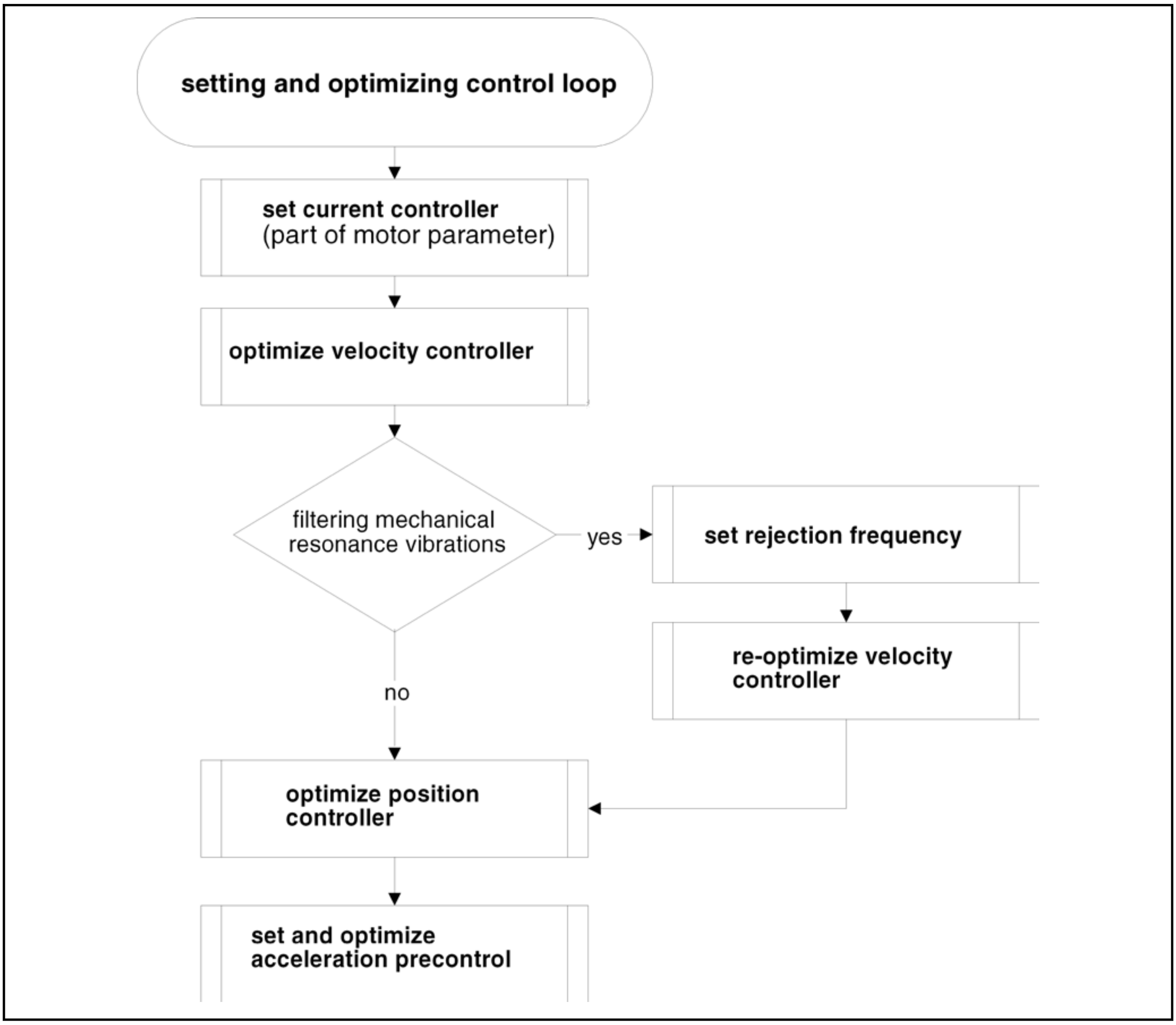

Fig.13-12: Setting and optimizing the control loop of synchronous linear drives.

☞ Refer to the functional description of the drive controller for more detailed 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 dynamics with 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-mass vibrational system", is mainly in the frequency range from 400 to 800 Hz. It depends on the rigidity of the mechanical system and the spatial expansion of the system.

In most cases, this "Two-mass vibrational system" has a clear resonant frequency that can be selectively suppressed by a rejection filter installed in the drive.

When the mechanical resonant frequency is suppressed, the dynamic properties of the velocity control loop and of the position control loop may, under certain circumstances, be improved as compared with closed-loop operation without rejection filter.

This leads to an increased profile accuracy and shorter 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!

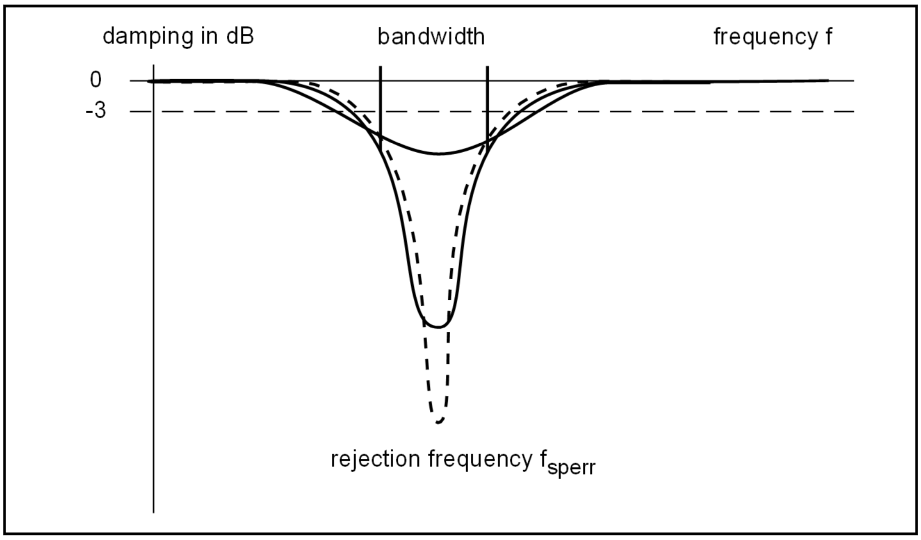

Fig. 13-13: Amplitude response of the rejection filter in relation to the bandwidth, qualitative

13.7.2 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.

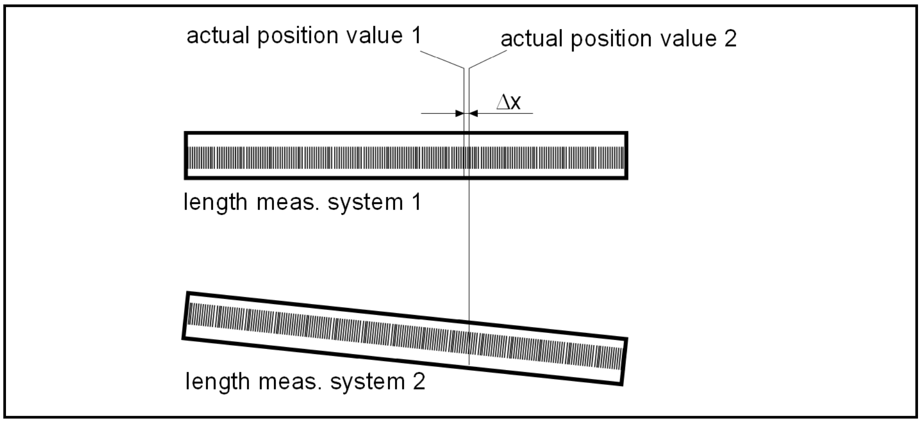

Fig.13-14: Possible misalignment with the linear scale of a Gantry axes

Parameter Settings

When using Gantry axes, your must ensure that the parameter settings of the following parameters are identical:

- Motor parameter
- 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.13-15: 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.13-16: 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.

13.7.3 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.

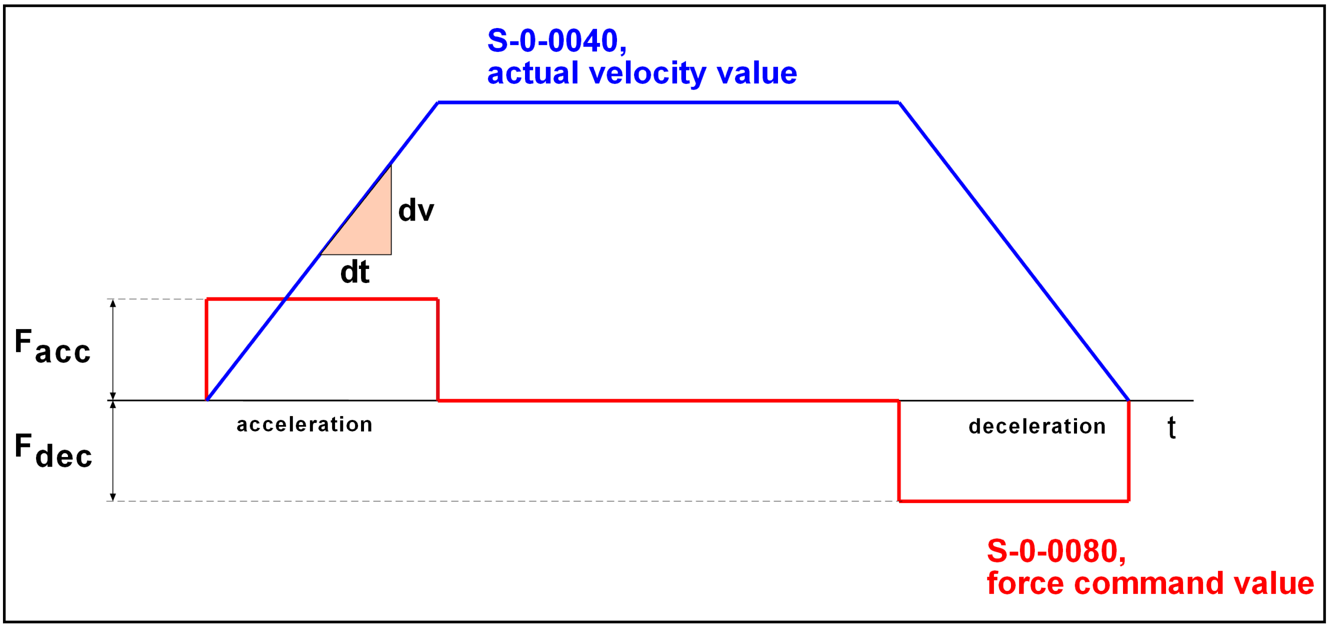

Fig. 13-17: Oscillogram of velocity and force

$$m = 30 \cdot F_N \cdot \left(\frac{F_{ACC} + F_{DEC}}{100\%} \right) \cdot \frac{\Delta t}{\Delta v}$$

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 %
Δv	Velocity change during constant acceleration in m/min Acceleration in m/min
Δt	Time change during constant acceleration in s

Fig.13-18: 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.

13.8 Maintenance and Check of Motor Components

13.8.1 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.

13.8.2 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! Also refer toChapter 9.3.4 on page 131.
- 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)

13.8.3 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.

13.9 Operation on External Controllers

Rate of rise of voltage

The isolation system of the motor underlies a higher dielectric load in converter operation than in a sinusoidal source voltage only. The voltage stress of the winding isolation in converter operation is mainly defined by the following factors:

- Crest value of voltage
- Rise time of impulse on the motor terminal
- Switching frequency of converter output
- Length of power cable to the motor

Main components are the switching times of converter output and the length of the power cable to the motor. The occured rates of rise of voltage on the motor may not exceed the specified limits from DIN VDE 0530-25 (VDE 0530-25):2009-08 (picture 14, limit curve A) of impulse voltage, measured on the motor terminals of two strands in depencence of the rise time.

☞ Outputs of IndraDrive converters keep this limits.

14 Appendix

14.1 Recommended Suppliers of Additional Components

14.1.1 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

14.1.2 Linear Scales

Bosch Rexroth AG
Maria-Theresien-Str. 23
97816 Lohr am Main, Germany
Internet: http://www.boschrexroth.com

14.1.3 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

14.1.4 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

14.1.5 Coolant Additives

NALCO Deutschland GmbH
Plankstr. 26
71691 Freiberg/Neckar, Germany
Fax +49(0)7141-703-239
e-mail: slund@nalco.com

14.1.6 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

14.1.7 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

14.1.8 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

14.1.9 Clamping Elemens for Linear Scales

Bosch Rexroth AG
Maria-Theresien-Str. 23
97816 Lohr am Main, Germany
Internet: http://www.boschrexroth.com

14.1.10 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

14.1.11 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

14.1.12 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 Service and Support

Our worldwide service network provides an optimized and efficient support. Our experts offer you advice and assistance should you have any queries. You can contact us **24/7**.

Service Germany

Our technology-oriented Competence Center in Lohr, Germany, is responsible for all your service-related queries for electric drive and controls.

Contact the **Service Helpdesk & Hotline** under:

Phone:	+49 9352 40 5060
Fax:	+49 9352 18 4941
E-mail:	service.svc@boschrexroth.de
Internet:	http://www.boschrexroth.com

Additional information on service, repair (e.g. delivery addresses) and training can be found on our internet sites.

Service worldwide

Outside Germany, please contact your local service office first. For hotline numbers, refer to the sales office addresses on the internet.

Preparing information

To be able to help you more quickly and efficiently, please have the following information ready:

- Detailed description of malfunction and circumstances resulting in the malfunction
- Type plate name of the affected products, in particular type codes and serial numbers
- Your contact data (phone and fax number as well as your email address)

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Notes

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