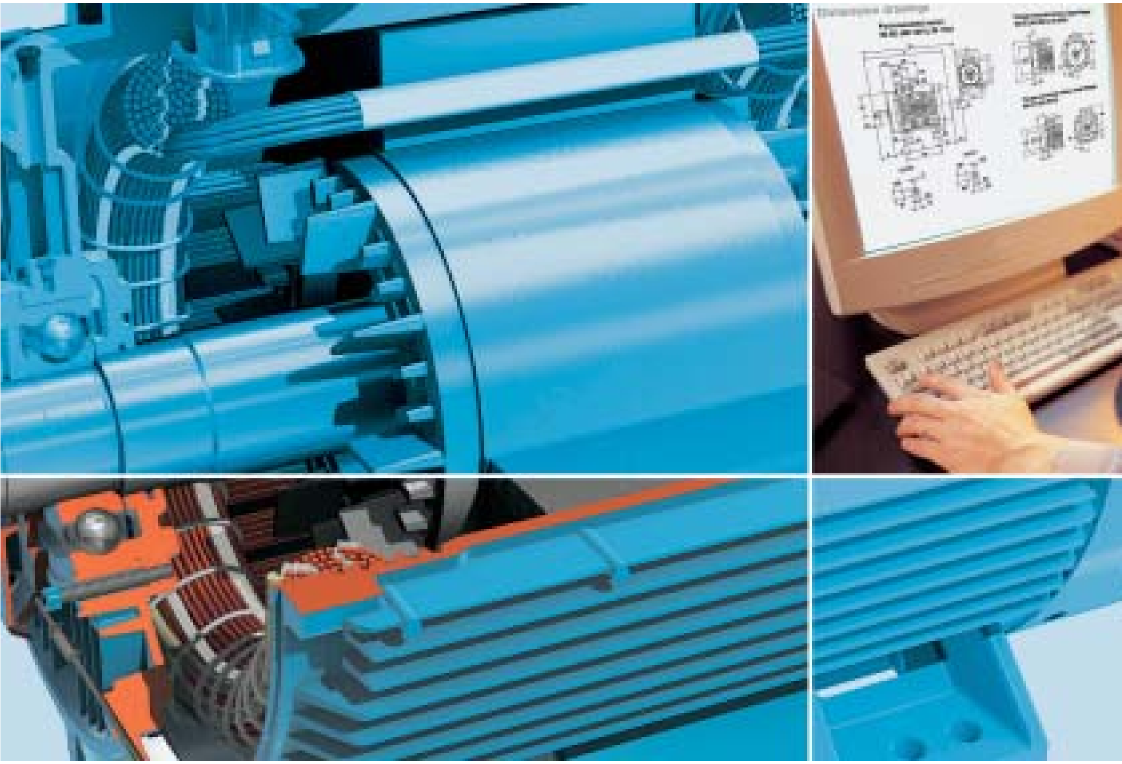
The Motor Guide



ABB

Motors are made by people

The Motor Guide

ABB

The Motor Guide- basic technical information about low voltage standard motors

LV Motors

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Second edition 2005

10. Variable Speed Drives

1

ABB Profile

1.1. The ABB Group

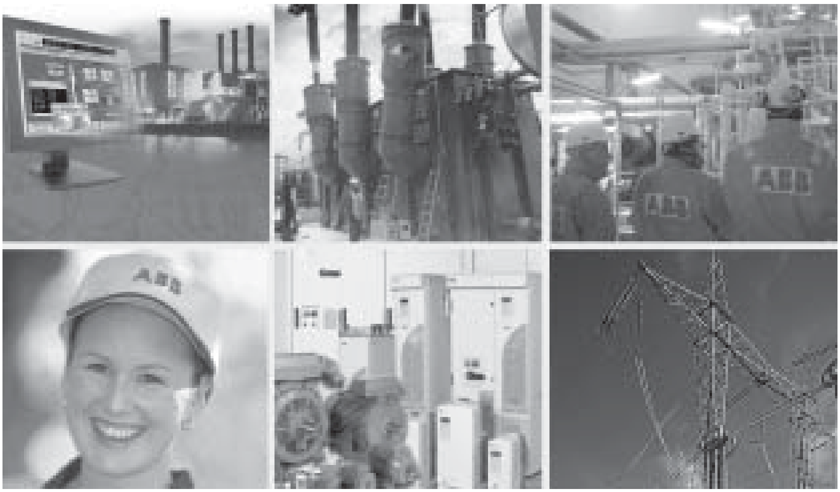
ABB: A world leader in electrical engineering

ABB (www.abb.com) is a leader in power and automation technologies that enable utility and industry customers to improve performance while lowering environmental impacts. The ABB Group of companies operates in around 100 countries and employs around 103,000 people.

ABB has streamlined its divisional structure to focus on two businesses: Power Technologies and Automation Technologies.

ABB Power Technologies serves electric, gas and water utilities as well as industrial and commercial customers, with a broad range of products, systems and services for power transmission, distribution and automation.

ABB Automation Technologies blends a robust product and service portfolio with end-user expertise and global presence to deliver solutions for control, motion, protection, and plant integration across the full range of process and utility industries.



1.2 ABB Low Voltage Motors

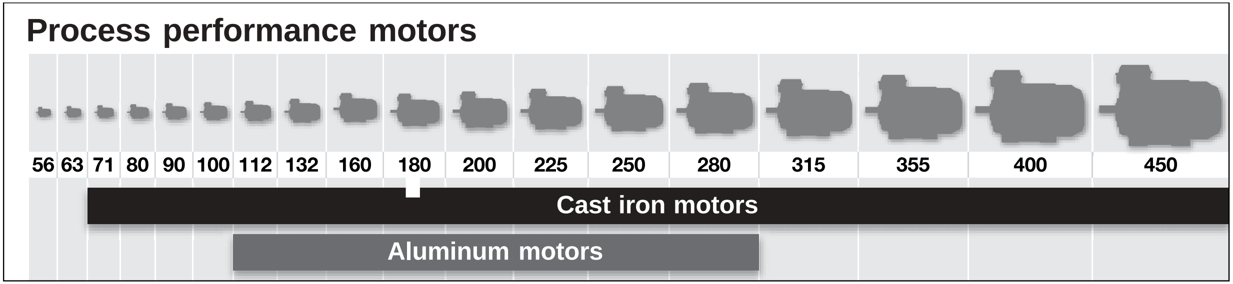
ABB has been manufacturing motors for over 100 years. Our products are designed to be reliable, efficient and cost effective, and we can supply motors for practically any application. A full range of services is available through our worldwide service organization, with the latest eBusiness systems providing round-the-clock access, easy ordering and fast delivery.

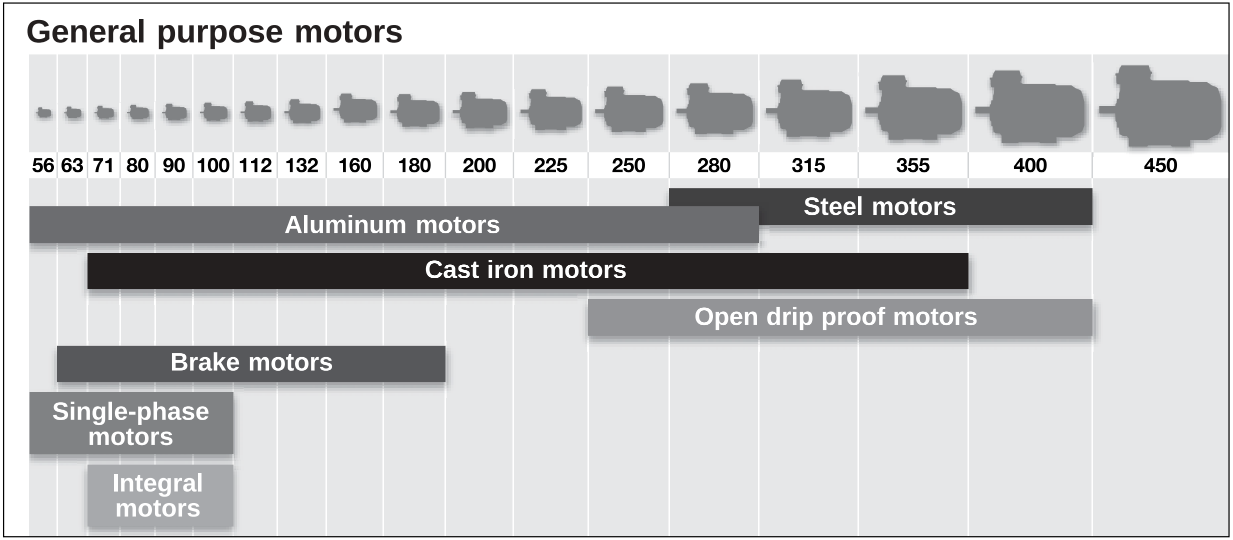
ABB's General purpose motors are readily available from central stock locations and distributors throughout the world. While designed for standard and straightforward uses, the motors can be modified to meet most specifications. Built to the highest manufacturing standards, the General purpose motors use the best materials sourced from around the world. This brings a quality and reliability that can see motors operating for over 30 years. Competitively priced, the motors meet EFF2 energy efficiency classification, with EFF1 as option.

ABB's Process performance motor is engineered to meet the most demanding applications found in industries including pulp and paper, water treatment, food and bewerage, metals and building materials. Such is the high design specification of the motor, when used in conjunction with applications in these industries, ABB is able to provide a 3-year warranty.

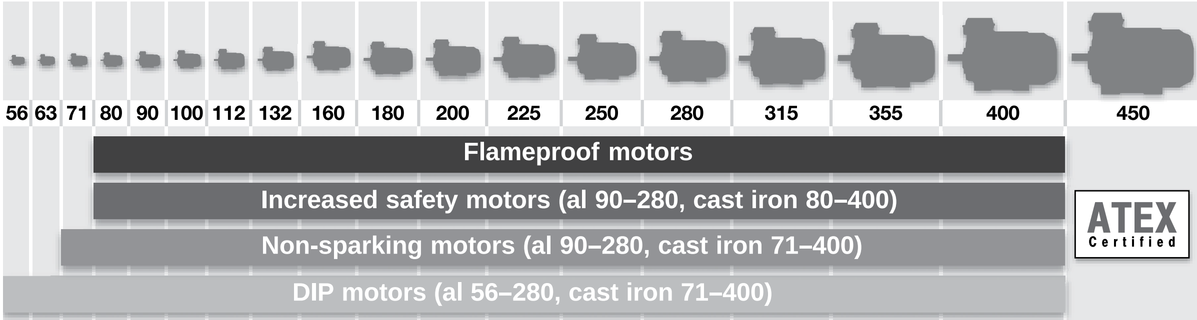
Built on the highest manufacturing standards, the process performance motors used the best materials sourced around the world. This brings a quality and reliability than can see motors operating for over 30 years. Competitively priced, the motors meet EFF1 energy efficiency classification.

Low Voltage Motors for All Applications

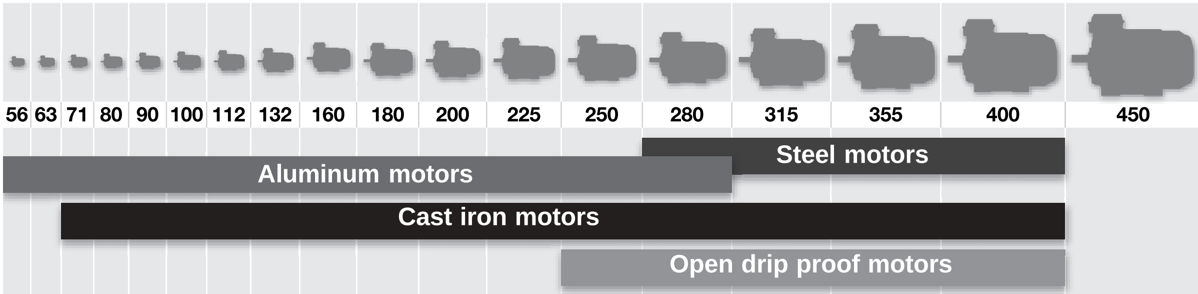




Motors for hazardous areas



Marine motors



1.3 Product range

ABB Motors' total product offer

ABB offers several comprehensive ranges of AC motors and generators.
We manufacture syncronous motors for even the ost demanding applications, and full range of low and high voltage induction motors. Our in-depth knowledge of vitually every type of industrial processing ensures we always specity the best for your needs.

Low voltage motors and generators

General purpose motors for standard applications
- Aluminum motors
- Steel motors
- Cast iron motors
- Open drip proof motors
- Global motors
- Brake motors
- Single phase motors
- Integral motors

Process performance motors for more demanding applications
- Aluminum motors
- Cast iron motors
- Motors for high ambient temperatures

NEMA motors

Motors for hazardous areas
- Flameproof motors
- Increased safety motors
- Non-sparking motors
- Dust ignition proof motors

Marine motors
- Aluminum motors
- Steel motors
- Cast iron motors
- Open drip proof motors

Other applications
- Permanent magnet motors
- High speed motors
- Wind turbine generators
- Smoke venting motors
- Water cooled motors
- Motors for roller table drives

High voltage and synchronous motors and generators
- High voltage cast iron motors
- Induction modular motors
- Slip ring motors
- Motors for hazardous areas
- Servomotors
- Synchronous motors and generators
- DC motors and generators

1.4 Quality, certificates

ABB motors factories are certified according to ISO 9001 quality standard and ISO 140001 environmental standard.

All ABB motors supplied are inspected and tested to ensure they are free from defects and have the desired design and performance characteristics.

Routine testing

This inspection is carried out on every motor. It involves checking that the motor possesses the necessary electrical strength and that its electrical and mechanical performance is satisfactory.

Type inspection

Type inspection is performed for one or more motors, to demonstrate that the characteristics and functions of the design are in accordance with the specifications of the manufacturer. Type inspection covers the inspection and testing of:

- electrical and mechanical operation
- electrical and mechanical strength
- temperature rise and efficiency
- overload capacity
- other special characteristics of the motor

1.4 Quality, certificates

Random inspection

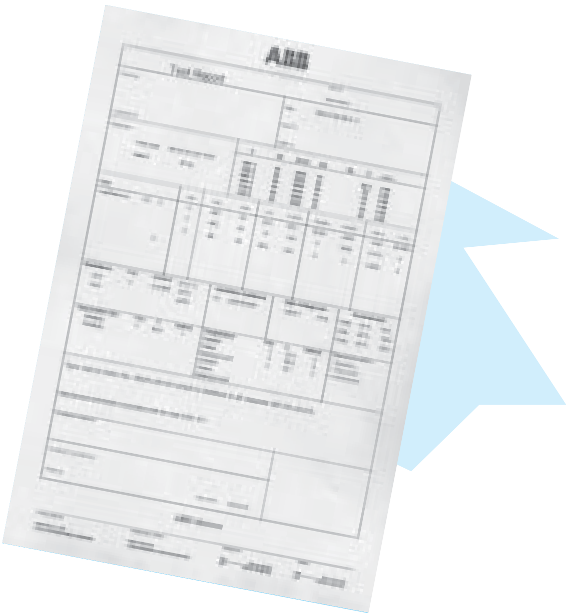
Subject to agreement at the time of ordering, purchasers may select a certain number of motors from a specific order for more detailed inspection and testing, similar in content to type inspection. The remaining motors undergo routine testing.

Special motor versions

Motors to be used onboard merchant vessels or in potentially explosive areas must undergo additional inspection and testing as laid down in the requirements of the relevant classification society or in applicable national or international standards.

Test reports

Type test reports providing typical performance values for purchased motors, together with a copy of the inspection and testing report will be issued to customers on request.



1.5 Information technology support

A wide selection of technical documentation, such as data sheets, dimension drawings and certificates from various authorities worldwide can be downloaded from the web site at www.abb.com/motors&drives.

Our easy-to-use motor selection tool, Online Motor Data Search enables motor selection, with motor-specific documentation, online. Also our dimensioning, MotSize, tool can be downloaded from our web-site.

To view and download information , simply follow easy-to-use navigation down to the product requested.

The following can be accessed from web:

- Accessories - detailed information on available motor options
- CAD outline drawings which can be copied into practically any AutoCad system
- Certificates of Approval - a selection of actual certificates from various authorities worldwide
- Declarations of Conformity - including voltage directives, CE markings etc.
- Manuals - available in several languages
- Maintenance - specific information, often not included in catalogues, such as special rules on how to store motors for long periods

1.5 Information technology support

- Motor dimension drawings - over 5000 motor dimension drawings, including frame size- and frame length-specific drawings for both low and high voltage standard and special motors
- Spare parts.

ABB web site is regularly updated and continuously developed.

CD-ROM

Also available on CD-ROM are:

- Complete motor catalogs
- CAD outline drawings
- Dimension drawings
- Motor Selection Program

1.6 Logistics System

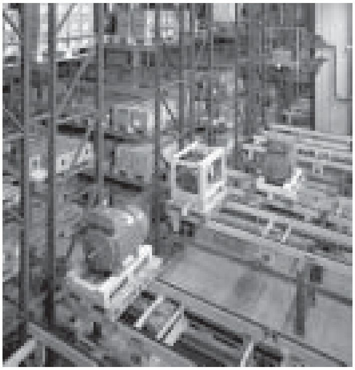
ABB established logistics system for low voltage motors in 1988. Today several other ABB products, for example low voltage drives utilizes the same concept.

The concept of a logistics system with central stock locations is unique in the electric motors market. The rapid and efficient service it provides has since become a powerful marketing and sales argument for ABB.

ABB's sales force is backed by the most sophisticated delivery system in the business. 300,000 motors and drives in 2,000 variations are available at the three Central Stock locations of the new European distribution network, in Germany, Sweden and Spain, which together have Europe covered. The Central Stock in Singapore handles South East Asia while Shanghai takes care of China and New Berlin, Wisconsin, of North America. In addition, many standard products are held by local distributors.

ABB's logistics system, with a common order management system (OMS), is the biggest commitment to motor and drives logistics by any manufacturer. It ensures the quick and correct delivery of any product, produced by any of ABB's motor or drive factories. The OMS also eliminates manual input of data at the central stock locations and guarantees a smooth processing of data.

Online access can be arranged via an EDI connection, directly to ABB OMS, or via Business Online (BOL), our web based customer interface to the OMS. This includes access to stock status and availability information. To get access to BOL, please contact your nearest sales office.



If you have special requirements, numerous factory supported design modifications are available within ABB's stocked standard motor ranges. Each site has a workshop for carrying out modifications. Some 70,000 modification variants are available. These include options such as different shafts, bearings, insulation, terminal boxes, end shields and even colours, as well as custom designs built to order. Modifications such as these can be carried out within 24 hours.

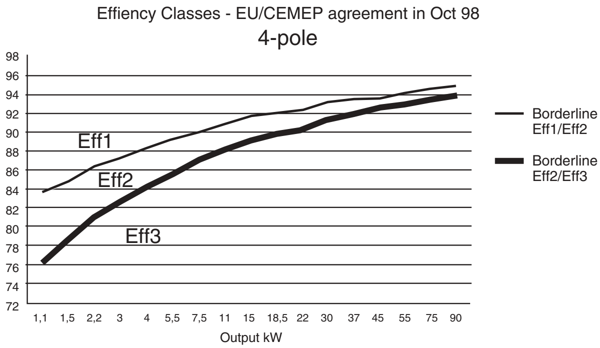
2

Energy saving and the environment

2.1 General

At the World Summit held in Kyoto, Japan, in December 1997, 55 nations of the world agreed to implement measures to reduce emissions to stabilise the global environment.

The 38 industrialised nations agreed to reduce their 1990 level greenhouse emissions by an average of 5% between 2008 and 2012. Further, the European Union made a commitment to reduce its emissions by 8%.



In October 1998, the European Union and CEMEP (The European Committee of Manufacturers of Electrical Machines and Power Electronics) agreed to introduce three efficiency classes for electric motors. This agreement forms part of the European Commission's aims to improve energy efficiency and reduce CO_2 emissions, and has already resulted in a considerable decrease of EFF3 motors, (the lowest efficiency class) on the market. In addition, an emission trade will be started within EU in 2005.

The burning of fossil fuels to generate electricity, primarily consumed by households and industry, is a major source of greenhouse gas emissions.

Industry will, therefore, have a major part to play in reducing harmful emissions. For instance by increasing the efficiency of their production processes, and installing energy efficient devices, industrial processes will consume less electricity. Which, in turn, will reduce the amount of electricity which must be generated to meet demand.

2.2 Energy Efficient Motors

Motors account for around 65 per cent of the electric energy consumed in industrial applications. Energy saving is dependent on the kW rating of the motor, the loading and the hours run. As such, higher efficiency motors can play a significant part in reducing CO_2 emissions.

ABB motors are designed to meet changing world attitudes towards energy efficiency and motor performance. The all round operational performance of these motors goes a long way towards fulfilling the commitments of world governments to the Kyoto Summit.

Industries can also help by recycling raw materials such as plastic and aluminum. This will save the electricity needed to produce these materials from their raw state (oil and aluminum or respectively).

2.2.1 Motors for EU motor efficiency levels

ABB is one of only a handful of leading motor manufacturers in Europe, to have a motor range to meet or exceed the minimum efficiencies stated in the highest level of the EU agreement for LV motors. These efficiency levels apply to 2- and 4-pole, three phase squirrel cage induction motors, rated for 400 V, 50 Hz, with S1 duty class and with the output 1.1-90 kW, which account for the largest volume on the market.

2.2.2 Motors according to EPAct requirements

The recently amended American Energy Policy and Conservation Act, generally referred to as EPAct, requires electric motors in the 0.7 - 150 kW (1 - 200 hp) range, manufactured in or imported to the United States or Canada, to meet the efficiency levels demanded by law.

ABB's wide product range includes motors that fulfil these requirements.

2.2.3 Global Motors

Global motors are motors that can be specified and used anywhere, multi-labelled to meet: UR, EPAct, CE, EFF1, CSA, EEF.
Range covers aluminum motors, 2- and 4-pole, IEC size 63 to 280.

2.2.3 Benefits of high efficiency motors

Reducing energy costs is one way companies can cut their overheads to remain competitive. Significant savings can be made by installing an energy efficient motor. This is particularly the case when considering either new installations or equipment packages, replacing oversized and underloaded motors, making major modifications to facilities or processes, or instead of repairing or rewinding a failed motor.

High efficiency motors offer savings through reduced energy costs, less downtime and a lower stock inventory. Even small rises in efficiency will make a substantial saving in the overall cost of a motor, taking into account both the operating and capital cost.

For example, in the UK, an 11 kW motor costs, typically, under GBP 500 to buy, yet over GBP 50,000 to run over a 10 year operating life. The purchase price is therefore around 1 per cent of the motor's total life cycle cost.

The table below compares the capital cost of various motor sizes with their running costs by showing approximately how long it takes to consume their own capital cost in energy cost.

Capital cost versus running cost (GBP)

Rating	5.5 kW	18.5 kW	90 kW	250 kW
Approx. cap cost	285	680	3,700	10,500
Typical efficiency	85 %	90 %	92 %	94 %
Input kW	6.47	20.56	97.83	265.96
Daily running cost	7.76	24.67	117.40	319.15
Days to consume capital cost	37	28	32	33

Assuming continuous duty at a tariff of GBP 0.05/kWh

All ABB motors are energy efficient as standard, available off the shelf in all standard frame sizes. There is also a range of High Effiency Motors available. They are suitable for all applications, including hazardous areas, and variable speed drive.

2.2.3 Benefits of high efficiency motors

An energy efficient motor produces the same output power (torque) but uses less electrical input power (kW) than a standard efficiency motor. This higher efficiency is achieved by using higher quality and thinner laminations in the stator to reduce core loss, more copper in the slots to reduce I^2R loss. Energy efficient motors also have reduced fan and stray losses.

There are three main motor efficiency testing standards, IEC 600 34-2 (EU), IEEE 112-1991 (USA), and JEC 37 (Japan). The main difference is that IEEE 112 measures the total losses by a direct method, thus giving the lowest values.
IEC 600 34-2 is an indirect method which assumes the additional losses to be 0.5 per cent, which is lower than real losses for small motors. JEC 37 is also an indirect method which assumes the additional losses to be zero, thus giving the highest values.

2.2.4 Energy saving, Life Cycle Assessment (LCA)

Life Cycle Assessment can show designers how to obtain environmental benefits in their products. The table below compares two standard 11 kW electric motors of different design. Motor A is manufactured by ABB Motors, and Motor X by a competitor. The ABB motor requires more copper and iron to manufacture than motor B, but this makes it more efficient in operation. This means that it uses less electricity than motor X over its lifetime.

Operating 8,000 hours per year for 15 years, the more efficient ABB motor will use 140,681 kWh, and the less efficient motor X, 177,978 kWh.

With an efficiency of 91.1 per cent, an ABB motor will lose 8.9 per cent of the 140,681 kWh. Motor X, with an efficiency of 89 per cent, will lose 11 per cent of the 177,978 kWh. The table shows the environmental aspects of these two motors based on their losses, manufacture and 96 per cent recycling. Evaluated according to the EPS scheme, motor A has a 21 per cent lower environmental impact.

Environmental aspects over full life cycle	**ABB Motor 11 kW**	**Motor X 11 kW**
Efficiency	91 %	89 %
Use of resources electricity generation average European mix		
Coal kg	16,370	20,690
Gas kg	2,070	2,620
Oil kg	3,240	4,090
Steel and other materials (kg)	32	29
Emissions (kg)	64,278	81,067
percentage CO_2	98	98
Total EPS[1]) indices	8,260 ELU[2])	10,430 ELU
	99.4 % from operation	99.5 % from operation

[1]) The Environmental Priority Strategies in Design. The EPS method includes five safeguard objects: Human health, biological diversity, biological production, resources and aesthetic values.

[2]) Environmental Load Limit, ELU, is used to estimate the input of the five safeguard objects of EPS.

2.3 ABB's Environmental Management Program

ABB is a leader in power and automation technologies that enables utility and industry customers to improve performance, whilst lowering environmental impact. We aspire to create value for our stakeholders by meeting the needs of our customers, employees and the communities where we undertake business.

We strive to reduce our own environmental impact. We contribute to eco-efficiency and environmental stewardship in the communities and countries where we operate. Our core businesses offer energy-efficient systems, products and services, which enables our customers to lower their use of energy and natural resources.

Environmental management is one of our highest business priorities and we are committed to:

- conducting our operations in an environmentally sound manner by applying environmental management systems, such as ISO 14001, in all our operations and by applying environmental principles, such as commitment to continual improvement, legal compliance and awareness training of employees, in all our operations worldwide
- promoting environmental responsibility along the value chain by encouraging and auditing suppliers, sub-contractors and customers to adopt international environmental standards
- developing our manufacturing processes with focus on energy and resource efficiency
- conducting regular audits of our facilities' environmental performance and in connection with acquisitions, divestments and mergers
- transferring eco-efficient technologies to developing countries
- developing and marketing products and systems which are resource efficient and facilitate use of renewable energy sources
- declaring environmental performance of our core products by publishing environmental product declarations based on life-cycle assessment
- including environmental aspects in the risk assessment of major customer projects
- ensuring transparency by producing an annual Sustainability report, based on GRI requirements and which is independently verified

The environmental policy is an integral part of ABB´s commitment to sustainability and is embedded in our strategies, processes and day-to-day business throughout the ABB Group.

2.4 ISO 14001

ISO 14001 is the international standard for environmental management systems. Set by a sub committee of the World Business Council for Sustainable Development, the overall aim of ISO 14001 is to support environmental protection and prevent pollution in balance with socio-economic needs.

The standard requires that organizations establish and maintain environmental management systems, and sets targets for environmental work. In addition to complying with all relevant environmental legislation, companies must commit to continuous improvement and prevention of pollution. ISO 14001 also enables the public to appraise an organization's environmental performance.

ABB has already made significant progress in applying ISO 14001 to sites around the world. By the end of 2003, around 400 manufacturing and service sites have implemented ISO 14001.

3

Standards

3.1 General Introduction

ABB low voltage standard motors and generators are of the totally enclosed, three phase squirrel cage type, built to comply with international IEC standards, CENELEC and relevant VDE-regulations, and DIN-standards. Motors conforming to other national and international specifications are also available on request.

All ABB motor production units are certified to ISO 14001 international quality standard and conform to all applicable EU Directives.

ABB strongly supports the drive to harmonize European standards and actively contributes to various working groups within both IEC and CENELEC.

International standards:

- EN 60034-1,2 5, 6, 7, 9
- NEMA MG – 1 1993

IEC	
Electrical	Mechanical
IEC 600 34-1	IEC 600 72
IEC 600 34-2	IEC 600 34-5
IEC 600 34-8	IEC 600 34-6
IEC 600 34-12	IEC 600 34-7
	IEC 600 34-9
	IEC 600 34-14

3.2 Direction of rotation

Motor cooling is independent of the direction of rotation, with the exception of certain larger 2-pole motors.

When the mains supply is connected to the stator terminals marked U,V and W, of a three phase motor, and the mains phase sequence is L1, L2, L3, the motor will rotate clockwise, as viewed from the D-end. The direction of rotation can be reversed by interchanging any two of the three conductors connected to the starter switch or motor.

3.3 Cooling

Designation system concerning methods of cooling refers to Standard IEC 600 34-6

Example

IC 4 (A) 1 (A) 6

International Cooling

Circuit arrangement
0: Free circulation (open circuit)
4: Frame surface cooled

Primary coolant
A for air (omitted for simplified designation)

Method of movement of primary coolant
0: Free convection
1: Self-circulation
6: Machine-mounted independent component

Secondary coolant
A for air (omitted for simplified designation)
W for water

Method of movement of secondary coolant
0: Free convection
1: Self-circulation
6: Machine-mounted independent component
8: Relative displacement

ABB can deliver motors as below :

IC 410: Totally enclosed motor without fan
IC 411: Totally enclosed standard motor, frame surface cooled with fan
IC 416: Totally enclosed motor with auxiliary fan motor
IC 418: Totally enclosed motor, frame surface cooled without fan
IC 01: Open motors
IC 31W: Inlet and outlet pipe or duct circulated: water cooled

Note :

Motors without fan can deliver same output power provided installation are according to IC 418.

3.3 Cooling

The air flow and the air speed between ribs of frame must meet minimum the figures given below as to shaft height.
Figures correspond 50 Hz net supply, with 60 Hz 20 % must be added.

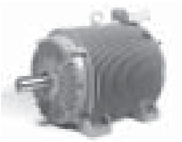
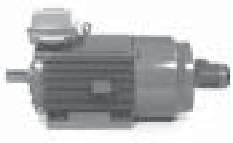
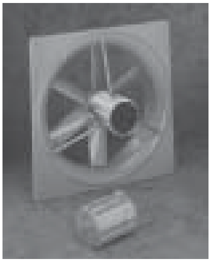
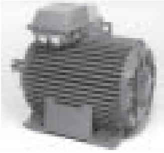
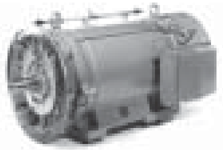
Air speed and Air flow :

Shaft height	Pole number	Air speed m/s	Air flow m³/s
56	2	1.5	0.12
	4	0.75	0.04
	6	NA	NA
	8	NA	NA
63	2	2	0.16
	4	1	0.07
	8	0.5	0.03
71	2	2.5	0.21
	4	1.5	0.10
	6	1.0	0.07
	8	0.75	0.06
80	2	3.5	0.31
	4	2.5	0.19
	6	1.5	0.12
	8	1.2	0.09
90	2	4.5	0.36
	4	3.0	0.28
	6	2.0	0.17
	8	1.6	0.14
100	2	7.5	0.69
	4	4.5	0.42
	6	3	0.25
	8	2.5	0.19
112	2	11	0.15
	4	7	0.10
	6	7	0.10
	8	7	0.10
132	2	12	0.25
	4	9	0.20
	6	8	0.15
	8	8	0.15
160	2	11	0.35
	4	8	0.25
	6	6	0.20
	8	3	0.10
180	2	11	0.45
	4	8	0.30
	6	6	0.25
	8	4	0.15
200	2	10	0.45
	4	8	0.35
	6	5	0.25
	8	5	0.25
225	2	10	0.50
	4	10	0.55
	6	9	0.45
	8	7	0.35
250	2	10	0.55
	4	12	0.65
	6	9	0.45
	8	6	0.30
280	2	9.6	0.46
	4	8.5	0.39
	6	6.5	0.32
	8	7.6	0.36
315	2	8.3	0.46
	4	9.4	0.56
	6	7.5	0.40
	8	7.6	0.43
355	2	10	0.82
	4	13	1.1
	6	11.5	1.0
	8	8.5	0.7
400	2	15	1.4
	4	15	1.5
	6	11	1.1
	8	8	0.8
450	2	15	2.0
	4	15	2.0
	6	13	1.7
	8	10	1.25

3.3 Cooling

Motors without fan according to IC 410 on request.

ABB Motors range:

Cooling designation	Motors range, frame sizes 56-450	
IC 410	Typical examples are roller table motors	
IC 411	Standard motors	
IC 416	Standard motors (Normally bigger frame sizes only equipped with auxiliary fan).	
IC 418	Fan application motors without a cooling fan, cooled by the airstream of the driven machine	
IC 01	Open drip proof motors	
IC 31 W	Water cooled motors	

3.4 Degrees of protection: IP code/IK code

Classification of degrees of protection provided by enclosures of rotating machines are refers to:

- Standard IEC 600 34-5 or EN 60529 for IP code
- Standard EN 50102 for IK code

IP protection:

Protection of persons against getting in contact with (or approaching) live parts and against contact with moving parts inside the enclosure. Also protection of the machine against ingress of solid foreign objects. Protection of machines against the harmful effects due to the ingress of water

IP 5 5

Characteristic letter — IP

Degree of protection to persons and to parts of the motors inside the enclosure — first digit (5)

2: Motors protected against solid objects greater than 12 mm
4: Motors protected against solid objects greater than 1 mm
5: Dust-protected motors
6: Dust-tight motors

Degree of protection provided by the enclosure with respect to harmful effects due to ingress of water — second digit (5)

3: Motors protected against spraying water
4: Motors protected against splashing water
5: Motors protected against water jets
6: Motors protected against heavy seas

IK code :

Classification of degrees of protection provided by enclosure for motors against external mechanical impacts.

IK 05

International mechanical protection — IK

Characteristic group — 05

Relation between IK code and impact energy:

IK code	IK 00	IK 01	IK 02	IK 03	IK 04	IK 05	IK 06	IK 07	IK 08	IK 09	IK 10
Impact energy Joule	*	0.15	0.2	0.35	0.5	0.7	1	2	5 ABB standard	10	20

** not protected according to EN 50102*

3.5 Standard voltage ranges

ABB can supply the global market with motors. To be able to meet your delivery requirements ABB products are designed to operate over wide voltage ranges. The codes S and D cover the world voltages.

Other voltage ranges available on request.

ABB single-speed motors motors are available in these voltage ranges.

Direct start or, with Δ-connection, also Y/Δ-start

Motor size	S 50 Hz	S 60 Hz	D 50 Hz	D 60 Hz
56-100	220-240 VΔ	-	380-420 VΔ	440-480 VΔ
	380-420 VY	440-480 VY	660-690 VY	-
112-132	220-240 VΔ	-	380-420 VΔ	440-480 VΔ
	380-420 VY	440-480 VY	660-690 VY	-
160-450[1]	220, 230 VΔ		380, 400, 415 YΔ	440-480 VΔ
	380, 400, 415 VY	440 VY	660, 690 VY	-

Motor size	E 50 Hz	E 60 Hz	F 50 Hz	F 60 Hz
56-100	500 VΔ	[2]	500 VY	[2]
112-132	500 VΔ	[2]	500 VY	[2]
160-450	500 VΔ	[2]	[2]	[2]

To obtain a poster about world voltages, please contact your nearest ABB motors sales office.

[1] The voltage range varies from type to type. Please always check the valid values in relevant product catalogues.

[2] On request.

3.5 Standard voltage ranges

Motors for other voltages

Motors wound for a given voltage at 50 Hz can also be used for other voltages. Efficiency, power factor and speed remain approximately the same.

Guaranteed values available on request.

Motor wound for	230 V		400 V		500 V		690 V	
Connected to (50 Hz)	220 V	230 V	380 V	415 V	500 V	550 V	660 V	690 V
% of values at 400 V, 50 Hz								
Output	100	100	100	100	100	100	100	100
I_N	182	174	105	98	80	75	61	58
I_S/I_N	90	100	90	106	100	119	90	100
T_S/T_N	90	100	90	106	100	119	90	100
T_{max}/T_N	90	100	90	106	100	119	90	100

3.6 Tolerances

	Efficiency by summation losses	Efficiency by input-output test	Power factor	Locked rotor current	Locked rotor torque	Pull-up torque
PN (kW) 150	-15% (1-η)	-15% (1-η)	-1/6 (1-cos φ)	+20%	-15% +25%	-15%
PN (kW) >150	-10 % (1-η)	-15% (1-η)	-1/6 (1-cos φ)	+20%	-15% +25%	-15%

	Moment of Inertia	Noise level
PN (kW) 150	±10%	+3 dB(A)

	Slip
PN (kW) <1	±30%
PN (kW) 1	±20%

Tolerances are in accordance with IEC 600 34-1 and based on test procedure in accordance with IEC 600 34-2.

3.7 Mounting arrangements

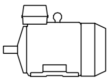
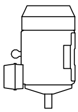
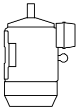
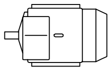
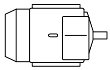
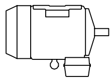
International standards
IM Mounting arrangements

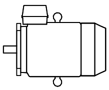
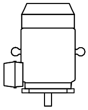
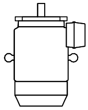
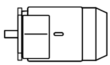
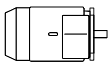
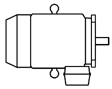
Example of designations according to Code II

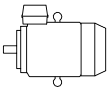
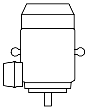
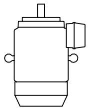
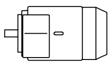
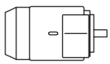
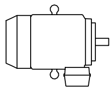
IM 1 00 1

- **Designation for international mounting** — IM
- **Type of construction, foot-mounted motor with two bearing end shields** — 1
- **Mounting arrangement, horizontal mounting with feet downwards etc.** — 00
- **External shaft extension, one cylindrical shaft extension etc.** — 1

Examples of common mounting arrangements

Code I	IM B3	IM V5	IM V6	IM B6	IM B7	IM B8
Code II	IM 1001	IM 1011	IM 1031	IM 1051	IM 1061	IM 1071
Foot-motor.						

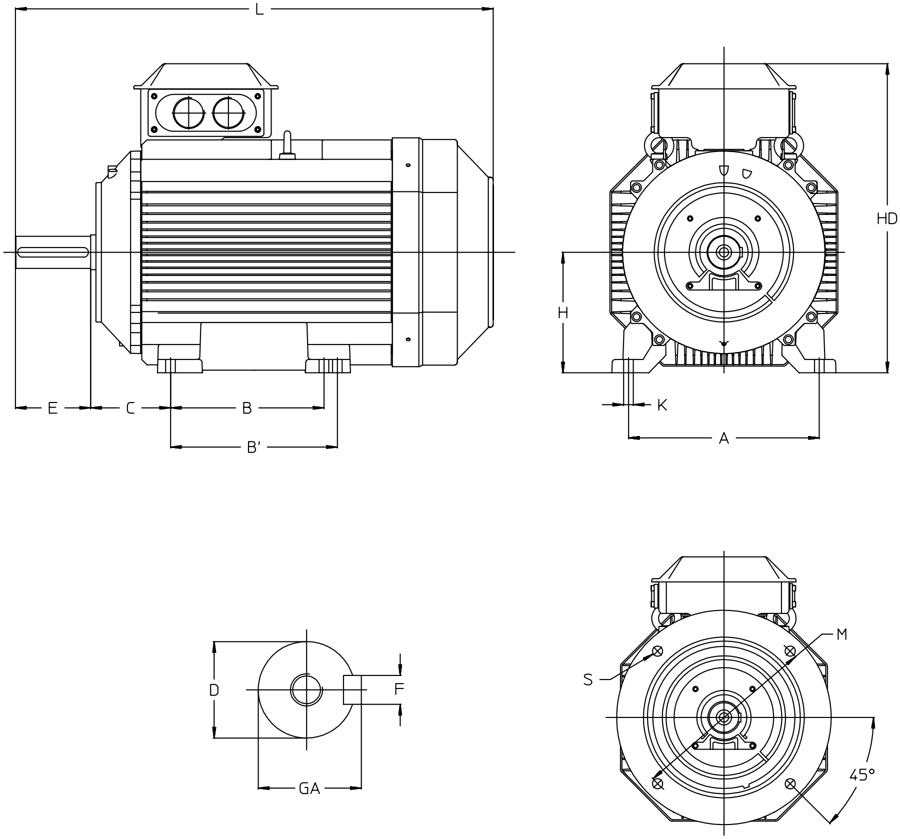
Code I	IM B5	IM V1	IM V3	*)	*)	*)
Code II	IM 3001	IM 3011	IM 3031	IM 3051	IM 3061	IM 3071
Flange-mounted motor, large flange with clearance fixing holes.						

Code I	IM B14	IM V18	IM V19	*)	*)	*)
Code II	IM 3601	IM 3611	IM 3631	IM 3651	IM 3661	IM 3671
Flange-mounted motor, small flange with tapped fixing holes.						

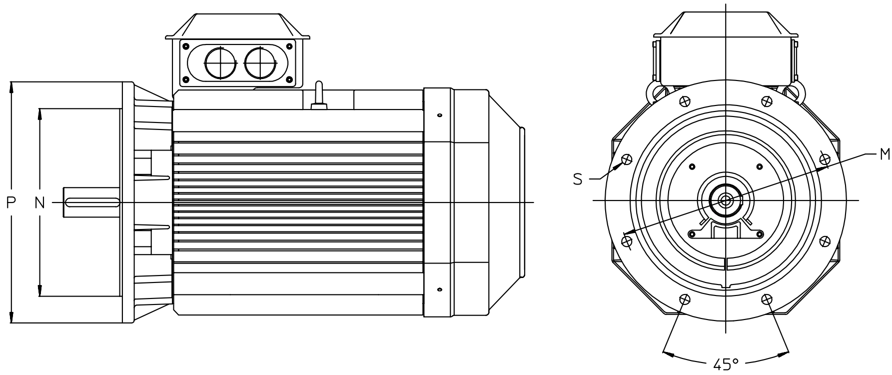
**) Not stated in in IEC 600 34-7*

3.8 Dimensions and power standards

Below is a typical dimension drawing which is available in catalogs, CD-ROM and on the web site.



3.8 Dimensions and power standards



Letter symbols for the most common dimensions:

A = distance between centre lines of fixing holes (end view)

B = distance between the centre lines of the fixing holes (side view)

B' = distance between the centre lines of the auxiliary fixing holes

C = distance the shoulder on the shaft at D-end to the centre line of the mounting holes in the nearest feet

D = diameter of the shaft extension at D-end

E = length of the shaft extension from the shoulder at the D-end

F = width of the keyway of the shaft extension at D-end

GA = distance from the top of the key to the opposite surface of the shaft extension at D-end

H = distance from the centre line of the shaft to the bottom of the feet

HD = distance from the top of the lifting eye, the terminal box or other most salient part mounted on the top of the motor to the bottom of the feet

K = diameter of the holes or width of the slots in the feet of the motor

L = overall length of the motor with a single shaft extension

M = pitch circle diameter of the fixing holes

N = diameter of the spigot

P = outside diameter of the flange, or in the case of a non-circular outline twice the maximum radial dimension

S = diameter of the fixing holes in the mounting flange or nominal diameter of thread.

Motor size	Shaft extension diameter mm		Rated output kW				Flange number	
	2 poles	4,6,8 poles	2 poles	4 poles	6 poles	8 poles	free holes	threaded holes
56	9	9	0.09 or 0.12	0.06 or 0.09				FT65 or FT85
63	11	11	0.18 or 0.25	0.12 or 0.18			FF115	FT75 or FT100
71	14	14	0.37 or 0.55	0.25 or 0.37			FF130	FT85 or FT115
80	19	19	0.75 or 1.1	0.55 or 0.75	0.37 or 0.55		FF165	FT100 or FT130
90 S	24	24	1.5	1.1	0.75	(0.37)	FF165	FT115 or FT130
90 L	24	24	2.2	1.5	1.1	(0.55)		
100 L	28	28	3	2.2 or 3	1.5	0.75 or 1.1	FF215	FT130 or FT165
112M	28	28	4	4	2.2	1.5	FF215	FT130 or FT165
132 S	38	38	5.5 or 7.5	5.5	3	2.2	FF265	(FT165 or FT215)
132 M	38	38	-	7.5	4-5.5	3	(FT265)	
160 M	42	42	11 or 15	11	7.5	4-5.5		(FT215)
160 L	42	42	18.5	15	11	7.5		
180 M	48	48	22	18.5	-	-	FF300	
180 L	48	48	-	22	15	11		
200 L	55	55	30 or 37	30	18.5-22	15	FF350	
225 S	55	60	-	37	-	18.5	FF400	
225 M	55	60	45	45	30	22		
250 M	60	65	55	55	37	30	FF500	
280 S	65	75	75	75	45	37	FF500	
280 M	65	75	90	90	55	45		
315 S	65	80	110	110	75	55	FF600	
315 M	65	80	132	132	90	75		

CENELEC harmonisation document, HD 231, lays down data for rated output and mounting, i.e. shaft height, fixing dimensions and shaft extension dimensions, for various degrees of protection and sizes.
It covers totally enclosed squirrel cage motors at 50 Hz, in frame sizes 56 to 315 M.

4

Electrical design

4.1 Insulation

ABB uses class F insulation systems for motors, which, with temperature rise B, is the most common requirement among industry today.

Class F insulation system

- Max ambient temperature 40° C
- Max permissible temperature rise 105 K
- Hotspot temperature margin + 10 K

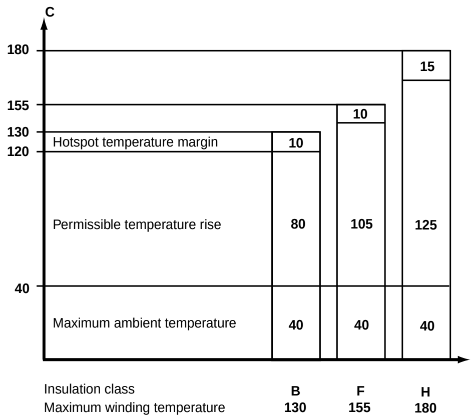
Class B rise

- Max ambient temperature 40° C
- Max permissible temperature rise 80 K
- Hotspot temperature margin + 10 K

Insulation system temperature class

- Class F 155° C
- Class B 130° C
- Class H 180° C

The use of Class F insulation with Class B temperature rise gives ABB products a 25° C safety margin. This can be used to increase the loading for limited periods, to operate at higher ambient temperatures or altitudes, or with greater voltage and frequency tolerances. It can also be used to extend insulation life. For instance, a 10 K temperature reduction will extend the insulation life.



Safety margins per insulation class

4.2 Ambient temperatures/high altitudes

Permitted output in high ambient temperatures or at high altitudes table

Basic motors are designed for operation in a maximum ambient temperature environment of 40° C and at a maximum altitude of 1000 meters above sea level. If a motor is to be operated in higher ambient temperatures, it should normally be derated according to the table below. Please note that when the output power of a standard motor is derated, the relative values in catalogs, such as I_S/I_N, will change.

Ambient temperature, ° C	30	40	45	50	55	60	70	80
Permitted output, % of rated output	107	100	96,5	93	90	86,5	79	70

Height above sea level, m	1000	1500	2000	2500	3000	3500	4000
Permitted output, % of rated output	100	96	92	88	84	80	76

4.3 Starting motors

Connection transients

It is important to remember that the term starting current refers to the steady-state rms value. This is the value measured when, after a few cycles, the transient phenomena have died out. The transient current, the peak value, may be about 2.5 times the steady-state starting current, but decays rapidly. The starting torque of the motor behaves in a similar way, and this should be borne in mind if the moment of inertia of the driven machine is high, since the stresses on the shaft and coupling can be very great.

Direct-On-Line (D.O.L.) starting

The simplest way to start a squirrel cage motor is to connect it directly to the mains supply. In which case, a direct-on-line (D.O.L) starter is the only starting equipment required. However, one limitation with this method is that it results in a high starting current. Even so, it is the preferred method, unless there are special reasons for avoiding it.

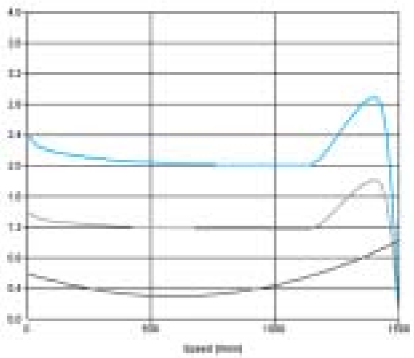
Y/Δ-starting

If it is necessary to restrict the starting current of a motor due to supply limitations, the Y/Δ method can be employed. This method, where for instance, a motor wound 400 VΔ is started with the winding Y connected, will reduce the starting current to about 30 per cent of the value for direct starting, and the starting torque will be reduced to about 25 per cent of the D.O.L value.

However, before using this method, one must first determine whether the reduced motor torque is sufficient to accelerate the load over the whole speed range.

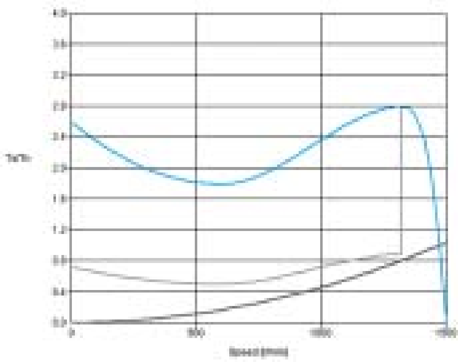
Please contact your nearest ABB sales office for the MotSize dimensioning tool, or download it from our web site.

D.O.L starting



Example taken from the MotSize calculation program showing D.O.L. starting curves (1. starting torque at U_n, 2. starting torque at 80 per cent U_n, 3 torque load) for a cast iron motor.

Y/Δ starting



Example taken from the MotSize calculation program showing Y/Δ. starting curves (1. starting torque at U_n, 2. starting torque at 80 per cent U_n, 3 torque load) for an aluminum motor.

ABB offers a full range of low voltage products for motor starting and control. For further information, please contact ABB.

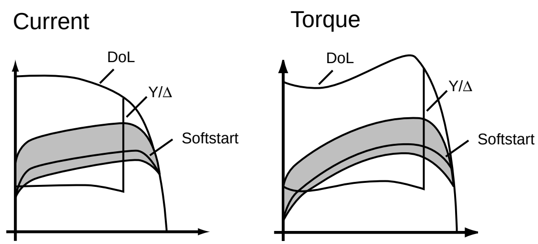
4.3.1 Soft starters

A soft starter limits the starting current while providing a smooth start. The magnitude of the starting current is directly dependent on the static torque requirement during a start, and on the mass of the load to be accelerated. The ABB soft starters are flexible and have adjustable settings to meet any application requirements. By gradually increasing the motor voltage during the start the result is a very smooth start. Well up in speed it is very common to by-pass the softstarter, to avoid the power loss from the semiconductors during continuous operation. To by-pass it is common to use an external mounted, AC-1 rated, contactor.

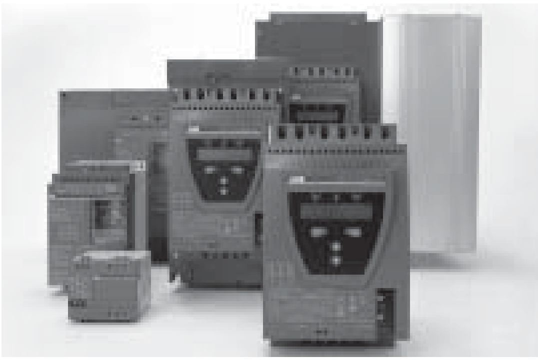
This contactor can also be built in into the softstarter like in the ABB's softstarter range PSTB. This is why this range is one of the most compact softstarters in the market.

In the ABB soft starter, the main circuit is controlled by semiconductors instead of mechanical contacts. Each phase is provided with two anti-parallel connected thyristors which allows current to be switched at any point within both positive and negative half cycles.

The lead time is controlled by the firing angle of the thyristor which, in turn, is controlled by the built in printed circuit board.



Soft starters reduce both current and torque



4.3.2 Starting time

Starting time is a function of load torque, inertia and motor torque. As the starting current is always very much higher than the rated current, an excessively long starting period will cause a harmful temperature rise in the motor. The high current also leads to electromechanical stresses.

Permitted starting time

In view of the temperature rise, the starting time must not exceed the time specified in the table.

The figures in the table apply to starting from normal operating temperature. When starting from cold, these can be doubled. Please note that the values below are for single-speed motors, values for two-speed motors on request.

Maximum starting times (seconds) for occasional starting

		Number of poles			
Motor size	**Starting method**	**2**	**4**	**6**	**8**
56	D.O.L.	25	40	NA	NA
63	D.O.L.	25	40	NA	NA
71	D.O.L.	20	20	40	40
80	D.O.L.	15	20	40	40
90	D.O.L.	10	20	35	40
100	D.O.L.	10	15	30	40
112	D.O.L.	20	15	25	50
	Y/Δ	60	45	75	150
132	D.O.L.	15	10	10	20
	Y/Δ	45	30	30	60
160	D.O.L.	15	15	20	20
	Y/Δ	45	45	60	60
180	D.O.L.	15	15	20	20
	Y/Δ	45	45	60	60
200	D.O.L.	15	15	20	20
	Y/Δ	45	45	60	60
225	D.O.L.	15	15	20	20
	Y/Δ	45	45	60	60
250	D.O.L.	15	15	20	20
	Y/Δ	45	45	60	60
280	D.O.L.	15	18	17	15
	Y/Δ	45	54	51	45
315	D.O.L.	15	18	16	12
	Y/Δ	45	54	48	36
355	D.O.L.	15	20	18	30
	Y/Δ	45	60	54	90
400	D.O.L.	15	20	18	30
	Y/Δ	45	60	54	90
450	D.O.L.	15	20	18	30
	Y/Δ	45	60	54	90

4.3.2 Starting time

Permitted frequency of starting and reversing

When a motor is subjected to frequent starting, it cannot be loaded at its rated output due to the thermal starting losses in the windings. Calculating the permissible output power can be based on the number of starts per hour, the moment of inertia of the load, and the speed of the load. Mechanical stresses may also impose a limit below that of thermal factors.

Permitted output power $P = P_N \sqrt{1 - \frac{m}{m_o}}$

P_N = rated output of motor in continuous duty

$m = x \cdot \frac{J_M + J'_L}{J_M}$

x = number of starts per hour

J_M = moment of inertia of motor in kgm^2

J'_L = moment of inertia of load in kgm^2, recalculated for the motor shaft, i.e. multiplied by $(\text{load speed}/\text{motor speed})^2$. The moment of inertia J (kgm^2) is equal to 1/4 GD^2 in kpm^2.

m_o = highest permitted number of starts per hour for motor at no load, as stated in the table at right.

4.3.2 Starting time

Highest permitted number of starts/hour at no load

	Number of poles			
Motor size	**2**	**4**	**6**	**8**
56	12000	9000	–	–
63B	11200	8700	–	–
71A	9100	8400	16800	15700
71B	7300	8000	16800	15700
80A	5900	8000	16800	11500
80B	4900	8000	16800	11500
90S	4200	7700	15000	11500
90L	3500	7000	12200	11500
100 L	2800	–	8400	–
100 LA	–	5200	–	11500
100 LB	–	4500	–	9400
112 M	1700	6000	9900	16000
132 (S, M)	1700	2900	4500	6600
160 MA	650	–	–	5000
160 M	650	1500	2750	5000
160 L	575	1500	2750	4900
180 M	400	1100	–	–
180 L	–	1100	1950	3500
200 LA	385	–	1900	–
200 L	385	1000	1800	3400
225 S	–	900	–	2350
225 M	300	900	1250	2350
250 M	300	900	1250	2350
280	125	375	500	750
315	75	250	375	500
355	50	175	250	350
400	50	175	250	350
450	on request			

4.3.3 Starting characteristics

Catalogs usually state a maximum starting time as a function of motor size and speed. However, there is now a standardized requirement in IEC 600 34-12 which specifies the permitted moment of inertia of the driven machine instead of the starting time. For small motors, the thermal stress is greatest in the stator winding, whilst for larger motors it is greatest in the rotor winding.

If the torque curves for the motor and the load are known, the starting time can be calculated by integrating the following equation:

$$T_M - T_L = (J_M + J_L) \times \frac{d\omega}{dt}$$

where

T_M = motor torque, Nm
T_L = load torque, Nm
J_M = moment of inertia of motor, kgm^2
J_L = moment of inertia of load, kgm^2
ω = motor angular velocity

In case of gearing T_L and J_L will be replaced by T'_L and J'_L correspondingly.

If the starting torque T_S and maximum torque T_{max} of the motor are known, together with the nature of the load, the starting time can be approximately calculated with the following equation:

$$t_{st} = (J_M + J_L) \times \frac{K_1}{T_{acc}}$$

where

t_{st} = starting time, s
T_{acc} = acceleration torque, $K_1 N_m$
K_1 = as per table below

Speed constant	poles 2	4	6	8	10	Frequency Hz
n_m	3000	1500	1000	750	600	50
K_1	314	157	104	78	62	
n_m	3600	1800	1200	900	720	60
K_1	377	188	125	94	75	

4.3.3 Starting characteristics

The average value for T_M

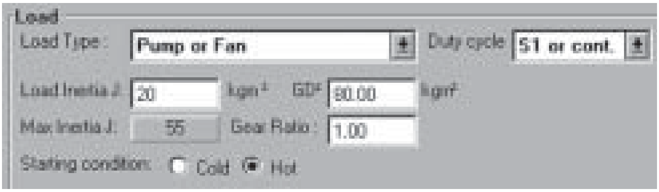
$$T_M = 0.45 \times (T_s + T_{max})$$

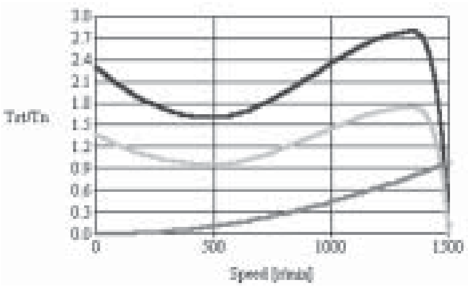
$$T_{acc} = T_M - K_L \times T_L$$

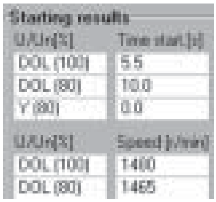
K_L can be obtained from the table below:

	Lift motion	Fan	Piston pump	Flywheel
K_L	1	1/3	0.5	0

Examples from the calculation program starting time







If there is gearing between the motor and the driven machine, the load torque must be recalculated to the motor speed, with the aid of the following formula:

$$T'_L = T_L \times \frac{n_L}{n_M}$$

The moment of inertia must also be recalculated using:

$$J'_L = J_L \times \left(\frac{n_L}{n_M}\right)^2$$

4.3.4 Examples of starting performance

Examples of starting performance with different load torques

4-pole motor, 160 kW, 1475 r/min

Torque of motor:

$T_N = 1040$ Nm

$T_s = 1.7 \times 1040 = 1768$ Nm

$T_{max} = 2.8 \times 1040 = 2912$ Nm

Moment of inertia of motor: $J_M = 2.5$ kgm^2

The load is geared down in a ratio of 1:2

Torque of load:

$T_L = 1600$ Nm at $n_L = \frac{n_M}{2}$ r/min

$T'_L = 1600 \times 1/2 = 800$ Nm at n_M r/min

Moment of inertia of load:

$J_L = 80$ kgm^2 at $n_L = \frac{n_M}{2}$ r/min

$J'_L = 80 \times \left(\frac{1}{2}\right)^2 = 20$ kgm^2 at n_M r/min

Total moment of inertia:

$J_M + J'_L$ at n_M r/min

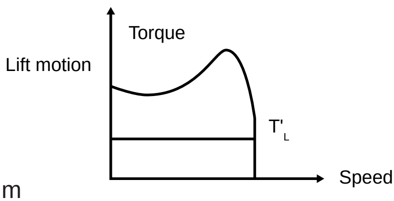
$2.5 + 20 = 22.5$ kgm^2

<u>Example 1:</u>

$T_L = 1600$ Nm $T'_L = 800$ Nm

Constant during acceleration

$T_{acc} = 0.45 \times (T_S + T_{max}) - T'_L$



$T_{acc} = 0.45 \times (1768 + 2912) - 800 = 1306$ Nm

$t_{st} = (J_M + J'_L) \times \frac{K_1}{T_{acc}}$

$t_{st} = 22.5 \times \frac{157}{1306} = 2.7$ s

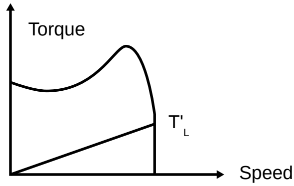
4.3.4 Examples of starting performance

<u>Example 2:</u>

T_L = 1600 Nm T'_L = 800 Nm

Linear increase during acceleration

Piston pump



$$T_{acc} = 0.45 \times (T_S + T_{max}) - \frac{1}{2} \times T'_L$$

$$T_{acc} = 0.45 \times (1768 + 2912) - \frac{1}{2} \times 800 = 1706 \text{ Nm}$$

$$t_{st} = (J_M + J'_L) \times \frac{K_1}{T_{acc}}$$

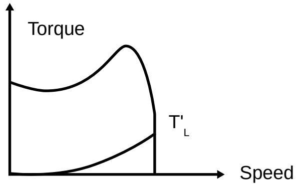
$$t_{st} = 22.5 \times \frac{157}{1706} = 2.1 \text{ s}$$

<u>Example 3:</u>

T_L = 1600 Nm T'_L = 800 Nm

Square-law increase during acceleration

Fan



$$T_{acc} = 0.45 \times (T_S + T_{max}) - \frac{1}{3} T'_L$$

$$T_{acc} = 0.45 \times (1768 + 2912) - \frac{1}{3} \times 800 = 1839 \text{ Nm}$$

$$t_{st} = (J_M + J'_L) \times \frac{K_1}{T_{acc}}$$

$$t_{st} = 22.5 \times \frac{157}{1839} = 1.9 \text{ s}$$

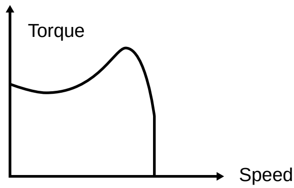
<u>Example 4:</u>

$T_L = 0$

$T_{acc} = 0.45 \times (T_S + T_{max})$

$T_{acc} = 0.45 \times (1768 + 2912) = 2106$ Nm

Flywheel



$$t_{st} = (J_M + J'_L) \times \frac{K_1}{T_{acc}}$$

$$t_{st} = 22.5 \times \frac{157}{2106} = 1.7 \text{ s}$$

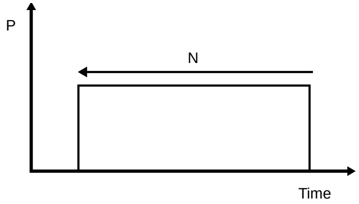
4.4 Duty types

The duty types are indicated by the symbols S1...S10 according to IEC 600 34-1 and VDE 0530 Part 1. The outputs given in the catalogs are based on continuous running duty, S1, with rated output.

In the absence of any indication of the rated duty type, continuous running duty is assumed when considering motor operation.

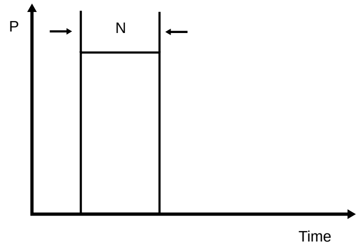
S1 Continuous running duty

Operation at constant load of sufficient duration for thermal equilibrium to be reached. Designation S1.



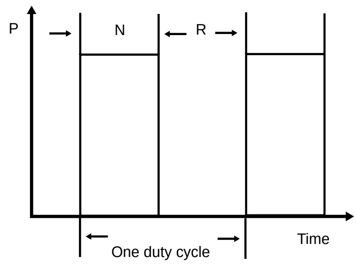
S2 Short-time duty

time, less than that required to reach thermal equilibrium, followed by a rest and
de-energized period of sufficient duration to allow motor temperature to return to the ambient, or cooling temperature. The values 10, 30, 60 and 90 minutes are recommended for the rated duration of the duty cycle. Designation e.g. S2 60 min.



S3 Intermittent duty

A sequence of identical duty cycles, each including a period of operation at constant load and a rest and de-energized period. The duty cycle is too short for thermal equilibrium to be reached. The starting current does not significantly affect the temperature rise.



Explanation to figures:

P = output power
D = acceleration
N = operation under rated condition
F = electrical braking
V = operation of no load
R = at rest and de-energized
P_N = full load

4.4 Duty types

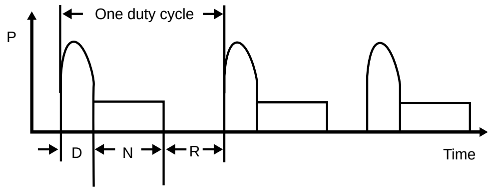
Recommended values for the cyclic duration factor are 15, 25, 40 and 60 per cent. The duration of one duty cycle is 10 min.

Designation e.g. S3 25%.

$$\text{Cyclic duration factor} = \frac{N}{N+R} \times 100\%$$

S4 Intermittent duty with starting

A sequence of identical duty cycles, each cycle including a significant period of starting, a period of operation at constant load, and a rest and de-energized period.



The cycle time is too short for thermal equilibrium to be reached. In this duty type, the motor is brought to rest by the load or by mechanical braking which does not thermally load the motor.

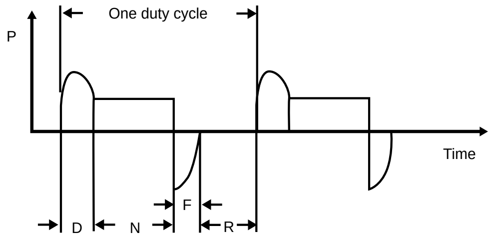
The following parameters are required to fully define the duty type: the cyclic duration factor, the number of duty cycles per hour (c/h), the moment of inertia of the load J_L and the moment of inertia of the motor J_M.

Designation e.g. S4 25 % 120 c/h $J_L = 0.2$ kgm^2 $J_M = 0.1$ kgm^2.

$$\text{Cyclic duration factor} = \frac{D+N}{D+N+R} \times 100\%$$

S5 Intermittent duty with starting and electrical braking

A sequence of identical duty cycles, each cycle consisting of a significant starting period, a period of operation at constant load, a period of rapid electric braking and a rest and de-energized period.



4.4 Duty types

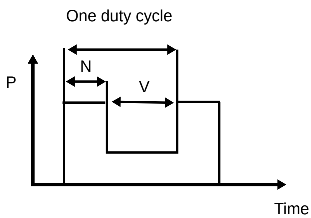
The duty cycles are too short for thermal equilibrium to be reached.
The following parameters are required to fully define the duty type: the cyclic duration factor; the number of duty cycles per hour (c/h), the moment of inertia of the load J_L and the moment of inertia of the motor J_M.

Designation e.g. S5 40 % 120 c/h J_L = 2.6 kgm^2
J_M = 1.3 kgm^2.

$$\text{Cyclic duration factor} = \frac{D+N+F}{D+N+F+R} \times 100\%$$

S6 Continuous operation periodic duty

A sequence of identical duty cycles, each cycle consisting of a period at constant load and a period of operation at no-load. The duty cycles are too short for thermal equilibrium to be reached.



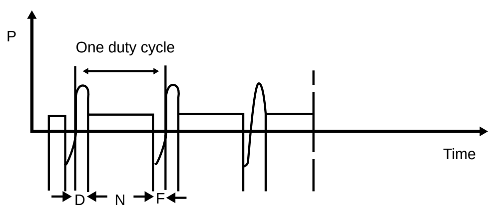
Recommended values for the cyclic duration factor are 15, 25, 40 and 60 per cent. The duration of the duty cycle is 10 min.

Designation e.g. S6 40%.

$$\text{Cyclic duration factor} = \frac{N}{N+V} \times 100\%$$

S7 Continuous operation periodic duty with electrical braking

A sequence of identical duty cycles, each cycle consisting of a starting period, a period of operation at constant load, and a period of braking. The braking method is electrical braking e.g. counter-current braking. The duty cycles are too short for thermal equilibrium to be reached.



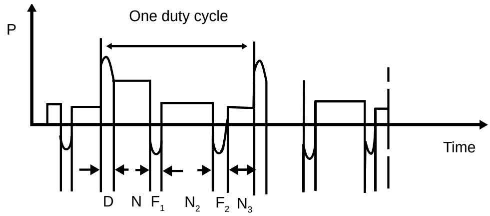
4.4 Duty types

The following parameters are required to fully define the duty type: the number of duty cycles per hour c/h, the moment of inertia of the load J_L and the moment of inertia of the motor J_M.

Designation e.g. S7 500 c/h J_L = 0.08 kgm² J_M =0.08 kgm².

8 Continuous-operation periodic duty with related load speed changes

A sequence of identical duty cycles, each cycle consisting of a starting period, a period of operation at constant load corresponding to a predetermined speed, followed by one or more periods of operation at other constant loads corresponding to different speeds. There is no rest and de-energized period.



The duty cycles are too short for thermal equilibrium to be reached.

This duty type is used for example by pole changing motors.

The following parameters are required to fully define the duty type: the number of duty cycles per hour c/h, the moment of inertia of the load J_L, the moment of inertia of the motor J_M, and the load, speed and cyclic duration factor for each speed of operation.

Designation e.g. S8 30 c/h J_L = 63.8 kgm² J_M 2.2. kgm².

24 kW	740r/min	30%
60 kW	1460r/min	30%
45 kW	980r/min	40%

$$\text{Cyclic duration factor 1} = \frac{D+N_1}{D+N_1+F_1+N_2+F_2+N_3} \times 100\%$$

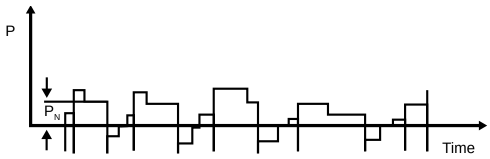
$$\text{Cyclic duration factor 2} = \frac{F_1+N_2}{D+N_1+F_1+N_2+F_2+N_3} \times 100\%$$

$$\text{Cyclic duration factor 3} = \frac{F_2+N_3}{D+N_1+F_1+N_2+F_2+N_3} \times 100\%$$

4.4 Duty types

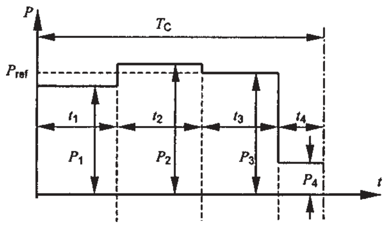
S9 Duty with non-periodic load and speed variations

A duty in which, generally, load and speed are varying non-periodically within the permissible operating range. This duty includes frequently applied overloads that may greatly exceed the full loads. For this duty type, suitable full load values should be taken as the basis of the overload concept.



S10 Duty with discrete constant loads and speeds

A duty consisting of a specific number of discrete values of load (or equivalent loading) and if applicable, speed, each load/speed combination being maintained for sufficient time to allow the machine to reach thermal equilibrium. The minimum load within a duty cycle may have the value zero (no-load or de-energized and at rest).



The appropriate abbreviation is S10, followed by the per unit quantities $p/\Delta t$ for the respective load and its duration and the per unit quantity TL for the relative thermal life expectancy of the insulation system. The reference value for the thermal life expectancy is the thermal life expectancy at rating for continous running duty and permissible limits of temperature rise based on duty type S1. For a time de-energized and at rest, the load shall be indicated by the letter r.

Examble: S10 $p/\Delta t$ = 1,1/0,4; 1/0,3; 0,9/0,2; r/0,1 TL = 0,6

The value of TL should be rounded off to the nearest multiple of 0,05.

4.4 Duty types

For this duty type a constant load appropriately selected and based on duty type S1 shall be taken as the reference value ('P_{ref}' in Fig.) for the discrete loads.

NOTE The discrete values of load will usually be equivalent loading based on integration over a period of time. It is not necessary that each load cycle be exactly the same, only that each load within a cycle be maintained for sufficient time for thermal equilibrium to be reached, ant that each load cycle be cabable of being integrated to give the same relative thermal life expectanly.

4.5 Uprating

Because of the lower temperature rise in the motor in short-time or intermittent duty, it is usually possible to take a higher output from the motor in these types of duty than in continuous duty, S1. The tables below show some examples of this. Attention must be paid to motor's maximum torque, T_{max}/T_N must be >1,8 referned to increased output.

Short-time duty, S2	Poles	Permitted output as % of rated output in S1 continuous duty for motor size:		
		56-100	112-250	280-450
30 min	2	105	125	130
	4-8	110	130	130
60 min	2-8	100	110	115

Intermittent duty, S3	Poles	Permitted output as % of rated output in S1 continuous duty for motor size:		
		56-100	112-250	280-450
15%	2	115	145	140
	4	140	145	140
	6, 8	140	140	140
25%	2	110	130	130
	4	130	130	130
	6, 8	135	125	130
40%	2	110	110	120
	4	120	110	120
	6, 8	125	108	120
60%	2	105	107	110
	4	110	107	110
	6, 8	115	105	110

4.6 Efficiency

The efficiency values for the rated output are listed in technical data tables in our product catalogs.

The table below illustrates typical values for part load. For instance, a motor with an efficiency value 90 has a 3/4 load value of 90, a 1/2 load value of 89 and a 1/4 value of 85. ABB can supply guaranteed part load values on request.

Efficiency η(%)									
2 - 4 poles					6 - 12 poles				
1.25 xP_N	1.00 xP_N	0.75 xP_N	0.50 xP_N	0.25 xP_N	1.25 xP_N	1.00 xP_N	0.75 xP_N	0.50 xP_N	0.25 xP_N
97	**97**	97	96	92	97	**97**	97	95	92
96	**96**	96	95	91	96	**96**	96	94	91
95	**95**	95	94	90	95	**95**	95	93	90
94	**94**	94	93	89	94	**94**	94	92	89
93	**93**	93	92	88	93	**93**	93	91	88
92	**92**	92	91	87	92	**92**	92	90	86
91	**91**	91	90	86	91	**91**	91	89	85
89	**90**	90	89	85	90	**90**	90	88	84
88	**89**	89	88	84	89	**89**	89	87	83
87	**88**	88	87	83	88	**88**	88	86	82
86	**87**	87	86	82	87	**87**	87	84	80
86	**86**	86	85	80	86	**86**	86	83	78
83	**85**	86	85	79	85	**85**	85	82	76
82	**84**	85	84	78	84	**84**	84	81	75
81	**83**	84	83	76	83	**83**	84	80	74
80	**82**	83	82	74	81	**82**	82	78	72
79	**81**	82	81	73	80	**81**	81	77	70
77	**80**	81	79	71	79	**80**	80	76	68
76	**79**	80	78	69	78	**79**	80	75	67
75	**78**	79	76	67	77	**78**	78	74	66
74	**77**	78	75	65	76	**77**	77	73	64
73	**76**	77	74	63	75	**76**	76	72	64
72	**75**	76	72	61	74	**75**	75	71	62
71	**74**	75	71	60	73	**74**	74	70	62
70	**73**	74	70	59	72	**73**	73	69	60
69	**72**	73	69	57	70	**72**	71	67	58
68	**71**	72	68	56	69	**71**	70	66	56
67	**70**	71	67	54	68	**70**	69	65	56

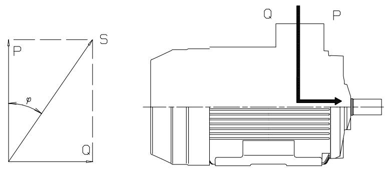
4.7 Power factor

A motor consumes both active power, which it converts into mechanical work, and also reactive power, which is needed for magnetization but does not perform any work.

The active and reactive power, represented in the diagram (below) by P and Q, together give the apparent power S. The ratio between the active power, measured in kW, and the apparent power, measured in kVA, is known as the power factor. The angle between P and S is usually designated φ. The power factor is equal to cosφ.

The power factor is usually between 0.7 and 0.9. It is lower for small motors and higher for large motors.

The power factor is determined by measuring the input power, voltage and current at rated output. The power factor stated is subject to a tolerance of (1-cosφ)/6



If there are many motors in an installation, a lot of reactive power will be consumed and therefore the power factor will be lower. For this reason, power suppliers sometimes require the power factor of an installation to be raised. This is done by connecting capacitors to the supply which absorb reactive power and thus raise the power factor.

4.7.1 Phase compensation

With phase compensation, the capacitors are usually connected in parallel with the motor, or group of motors. However, in some cases, over-compensation can cause an induction motor to self-excite and run as a generator. Therefore, to avoid complications, it is normal practice not to compensate for more than the no-load current of the motor.

The capacitors must not be connected in parallel with single phases of the winding; such an arrangement may make the motor difficult or impossible to start with star Δ starting.

4.7.1 Phase compensation

If a two-speed motor with separate windings has phase compensation on both windings, the capacitors should not remain in circuit on the unused winding. Under certain circumstances, such capacitors can cause increased heating of the winding and possibly also vibration.

The following formula is used to calculate the size (per phase) of a capacitor for a mains frequency of 50 Hz:

$$C = 3.2 \cdot 10^6 \cdot \frac{Q}{U_2}$$

where C = capacitance, µF
U = capacitor voltage, V
Q = reactive power, kvar.

The reactive power is obtained using the formula:

$$Q = K \cdot P \frac{P}{\eta}$$

where K = constant from table on right
P = rated power of motor, kW
η = effiency of motor

cos φ without compen-sation	Constant K Compensation to cos φ = 0.95	0.90	0.85	0.80
0.50	1.403	1.248	1.112	0.982
0.51	1.358	1.202	1.067	0.936
0.52	1.314	1.158	1.023	0.892
0.53	1.271	1.116	0.980	0.850
0.54	1.230	1.074	0.939	0.808
0.55	1.190	1.034	0.898	0.768
0.56	1.150	0.995	0.859	0.729
0.57	1.113	0.957	0.822	0.691
0.58	1.076	0.920	0.785	0.654
0.59	1.040	0.884	0.748	0.618
0.60	1.005	0.849	0.713	0.583
0.61	0.970	0.815	0.679	0.548
0.62	0.937	0.781	0.646	0.515
0.63	0.904	0.748	0.613	0.482
0.64	0.872	0.716	0.581	0.450
0.65	0.841	0.685	0.549	0.419
0.66	0.810	0.654	0.518	0.388
0.67	0.779	0.624	0.488	0.358
0.68	0.750	0.594	0.458	0.328
0.69	0.720	0.565	0.429	0.298
0.70	0.692	0.536	0.400	0.270
0.71	0.663	0.507	0.372	0.241
0.72	0.635	0.480	0.344	0.214
0.73	0.608	0.452	0.316	0.186
0.74	0.580	0.425	0.289	0.158
0.75	0.553	0.398	0.262	0.132
0.76	0.527	0.371	0.235	0.105
0.77	0.500	0.344	0.209	0.078
0.78	0.474	0.318	0.182	0.052
0.79	0.447	0.292	0.156	0.026
0.80	0.421	0.266	0.130	
0.81	0.395	0.240	0.104	
0.82	0.369	0.214	0.078	
0.83	0.343	0.188	0.052	
0.84	0.317	0.162	0.026	
0.85	0.291	0.135		
0.86	0.265	0.109		
0.87	0.238	0.082		
0.88	0.211	0.055		
0.89	0.184	0.027		
0.90	0.156			

4.7.2 Power factor values

The power factor values for the rated output are listed in technical data tables in our product catalogs.

The table below illustrates typical values. ABB can supply guaranteed values on request.

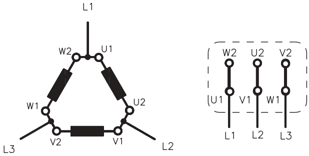
As the following example illustrates, a motor with a power factor 0.85 has 3/4 load value of 0.81, 1/2 load value 0.72 and 1/4 value 0.54.

(Power factor cos φ)

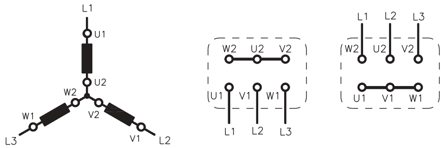
2 - 4 poles					**6 - 12 poles**				
1.25 xP_N	1.00 xP_N	0.75 xP_N	0.50 xP_N	0.25 xP_N	1.25 xP_N	1.00 xP_N	0.75 xP_N	0.50 xP_N	0.25 xP_N
0.92	**0.92**	0.90	0.84	0.68	0.92	**0.92**	0.90	0.84	0.68
0.91	**0.91**	0.89	0.83	0.66	0.91	**0.91**	0.89	0.83	0.66
0.90	**0.90**	0.88	0.82	0.64	0.90	**0.90**	0.88	0.82	0.64
0.89	**0.89**	0.87	0.81	0.62	0.89	**0.89**	0.87	0.81	0.62
0.88	**0.88**	0.86	0.80	0.60	0.88	**0.88**	0.86	0.80	0.60
0.88	**0.87**	0.84	0.76	0.58	0.88	**0.87**	0.84	0.76	0.58
0.87	**0.86**	0.82	0.73	0.56	0.87	**0.86**	0.82	0.73	0.56
0.86	**0.85**	0.81	0.72	0.54	0.86	**0.85**	0.81	0.72	0.54
0.85	**0.84**	0.80	0.71	0.52	0.85	**0.84**	0.80	0.71	0.52
0.84	**0.83**	0.78	0.70	0.50	0.84	**0.83**	0.78	0.70	0.50
0.84	**0.82**	0.76	0.66	0.46	0.84	**0.82**	0.76	0.66	0.46
0.84	**0.81**	0.74	0.63	0.43	0.84	**0.81**	0.74	0.63	0.43
0.83	**0.80**	0.73	0.60	0.40	0.83	**0.80**	0.73	0.60	0.40
0.82	**0.79**	0.72	0.59	0.38	0.82	**0.79**	0.72	0.59	0.38
0.82	**0.78**	0.71	0.58	0.36	0.82	**0.78**	0.71	0.58	0.36
0.81	**0.77**	0.69	0.55	0.36	0.81	**0.77**	0.69	0.55	0.36
0.81	**0.76**	0.68	0.54	0.34	0.81	**0.76**	0.68	0.54	0.34
0.80	**0.75**	0.67	0.53	0.34	0.80	**0.75**	0.67	0.53	0.34
0.79	**0.74**	0.66	0.52	0.32	0.79	**0.74**	0.66	0.52	0.32
0.78	**0.73**	0.65	0.51	0.32	0.78	**0.73**	0.65	0.51	0.32
0.78	**0.72**	0.62	0.48	0.30	0.78	**0.72**	0.62	0.48	0.30
0.78	**0.71**	0.61	0.47	0.30	0.78	**0.71**	0.61	0.47	0.30
0.77	**0.70**	0.60	0.46	0.30	0.77	**0.70**	0.60	0.46	0.30

4.8 Connection diagrams

Connection of three phase, single speed motors



Δ-connection



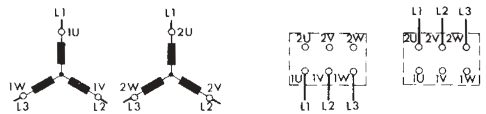
Y connection

Connection of two-speed motors

Two-speed motors are normally connected as illustrated below; direction of rotation as given on page 35. Motors of normal design have six terminals and one earth terminal in the terminal box. Motors with two separate windings are normally Δ-Δ connected. They can also be Y/Y, Y/Δ or Δ/Y connected. Motors with one winding, Dahlander-connection, are connected Δ/YY when designed for constant torque drives. For fan drive, the connection is Y/YY.
A connection diagram is supplied with every motor.

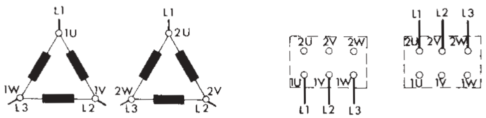
When starting a motor using Y Δ connection, one must always refer to the connection diagram supplied by the starter manufacturer.

1. Two separatate windings Y/Y



Low speed | High speed | Low speed | High speed

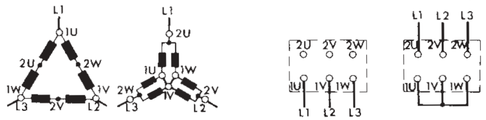
2. Two separate windings Δ/Δ



Low speed | High speed | Low speed | High speed

3. Dahlander-connection Δ/YY

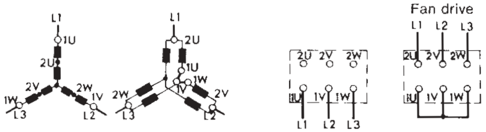
Constant torque drive



Low speed | High speed | Low speed | High speed

4. Dahlander-connection Y/YY

Fan drive

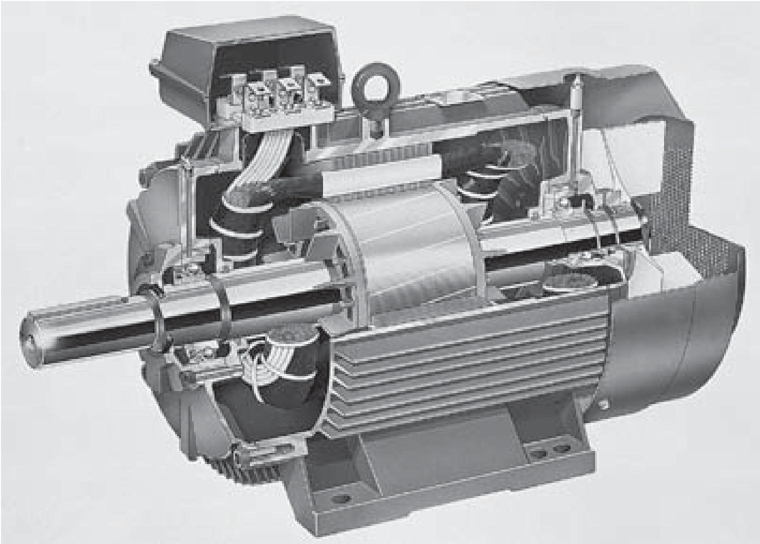


Low speed | High speed | Low speed | High speed

5

Mechanical design

5 Mechanical design



5.1 Frame constructions

Modern totally enclosed squirrel cage motors are available in a choice of aluminum, steel and cast iron frames and open drip proof motors in steel frames for different application areas.

Motor Frame Construction

STANDARD	56	63	71	80	90	100	112	132	160	180	200	250	280	315	355	400	450
Aluminum Frame	€	•	•	•	•	•	•	•	•	•	•	•	•				
Steel Frame													•	•	•	•	
Cast Iron Frame			•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
HAZARDOUS AREA																	
EEx e, EEx nA (al. & cast iron)			•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
EEx d, EEx de (cast iron)				•	•	•	•	•	•	•	•	•	•	•	•	•	
DIP (al & cast iron)	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•		
OPEN DRIP PROOF (steel frame)												•	•	•	•	•	
MARINE		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
SINGLE PHASE (aluminum)		•	•	•	•	•											
BRAKE MOTORS		•	•	•	•	•	•	•	•								

5.2 Terminal boxes

Terminal boxes are mounted either on the top of the motor, or on either side of the motor.

Motor size and frame material	On top	Terminal box Right side	Left side
56-180 aluminum motors[1)]	Standard	-	-
200-280 aluminum motors[1)]	Standard	Option	Option
71; 450 cast iron motors	Standard	-	-
80-250 cast iron motors	Standard	Option	Option
280-400 cast iron motors	Standard	Standard	Standard
280-400 steel motors	Standard	Standard	Standard

Non-standard design of terminal boxes, eg size, degree of protection, are available as options.

The terminal box of aluminum motors in sizes 56 to 180[1)] are provided with knockout openings. The sizes 200-250[1)] have a terminal box with two gland plates. The terminal boxes of cast iron motors in sizes 71 to 250 are equipped with blank cover plates for connection flanges. In motor sizes 280 to 450 the terminal box is equipped with cable glands or cable boxes. Cable glands for all other motors available as option.

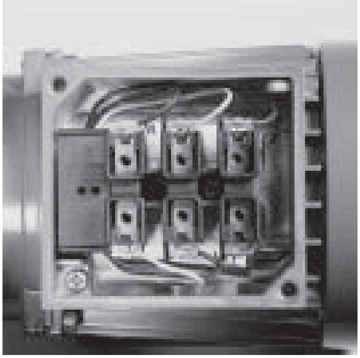
The terminal box of aluminum motors allow cable entry from both sides. The terminal box of cast iron motors in sizes 71 to 280 can be rotated 4x90° and in sizes 280 to 450 2x180°, to allow cable entry from either side of the motor.

Degree of protection of standard terminal box is IP 55.

[1)] Information may vary from type to type, please always check in the relevant product catalogs.

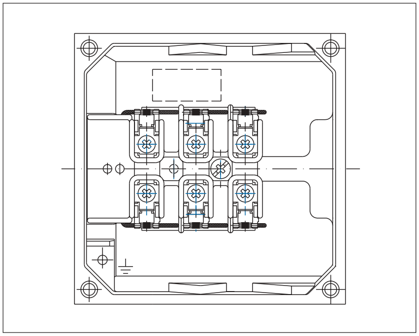
5.2 Terminal boxes

To ensure suitable terminations are supplied for the motor, please specify cable type, quantity and size when ordering.

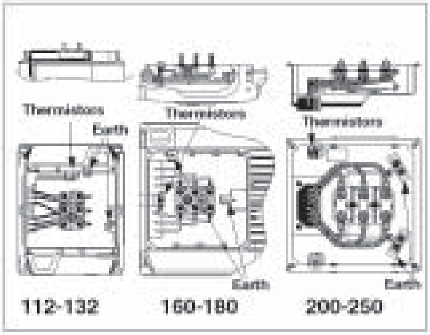


Terminal box of a cast iron motor and of an aluminum motor.

Terminal Box in aluminum motors, sizes 90-100



Terminal Box in aluminum motors, sizes 112-280



5.2 Terminal boxes

Co-ordination of terminal boxes and cable entries

If no cable specification is given on the order, it will be assumed to be PVC insulated and termination parts will be supplied in accordance with the following table.

Deviations from the standard design as per the following tables are available on request.

Coordination of terminal box and cable entry of steel and cast iron motors

Motor size	Opening	Cable entry	Max. connection Cu-cable area	Terminal bolt size
71	Tapped holes	2 x M 16	6 mm²	M4
80-90	Tapped holes	2 x M 25	6 mm²	M4
100, 112	Tapped holes	2 x M 32	16 mm²	M5
132	Tapped holes	2 x M 32	16 mm²	M5
160	Gland plate	2 x M 40	25 mm²	M6
180	Gland plate	2 x M 40	25 mm²	M6
200	Gland plate	2 x M 63	35 mm²	M10
225	Gland plate	2 x M 63	50 mm²	M10
250	Gland plate	2 x M 63	70 mm²	M10
280	Cable gland/box	2 x M 63	2 x 150 mm²	M12
315 SA	Cable gland/box	2 x M 63	2 x 240 mm²	M12
315 S_, M_, L_	Cable gland/box	2 x M 63	2 x 240 mm²	M12
355 S M_	Cable gland/box	2 x M 63, 2∅48-60	4 x 240 mm²	M12
355 M_, L_	Cable gland/box	2 x M 63, 2∅48-60	4 x 240 mm²	M12
400L, LK	Cable gland/box	2∅80	4 x 240 mm²	M12
450	Cable box	2∅80	4 or 6x240 mm²	M12

Coordination of terminal box and cable entry of aluminum motors

Motor size	Opening	Cable entry	Max. connection Cu-cable area	Terminal bolt size
56	Knockout openings	2 x 2 x Pg 11	2.5 mm²	Screw terminal
63	Knockout openings	2 x 2 x Pg 11	2.5 mm²	Screw terminal
71-100	Knockout openings	2 x 2 x Pg 16	2.5 mm²	Screw terminal
112, 132	Knockout openings	2 x (Pg 21+ Pg 16)	10 mm²	M5
160, 180	Knockout openings	2 x (2 x Pg 29+ 1Pg 11)	35 mm²	M6
200-280	Gland plate	2 x Pg 29, 42	70 mm²	M10

5.3 Bearings

Motors are normally fitted with single row deep groove ball bearings. The complete bearing designation is stated on the rating plate of most motor types.

If the bearing in the D-end of the motor is replaced with a roller bearing NU- or NJ-, higher radial forces can be handled. Roller bearings are especially suitable for belt drive applications.

When there are high axial forces, angular-contact ball bearings should be used. This version is available on request. When ordering a motor with angular-contact bearings, the method of mounting and direction and magnitude of the axial force must be specified.

Please see the respective product catalog for more specific details about bearings.

Bearing life

The normal life L10 of a bearing is defined, according to ISO, as the number of operating hours achieved or exceeded by 90 per cent of identical bearings in a large test series under certain specific conditions. 50 per cent of the bearings achieve at least five times this figure.

Bearing size

Reliability is the main criteria for bearing size design, taking into account the most common types of application, load of the motor and motor size. ABB uses 63 series bearings which are of robust design for longer life and higher loadability. 62 series bearings have lower noise levels, higher maximum speeds, and lower losses.

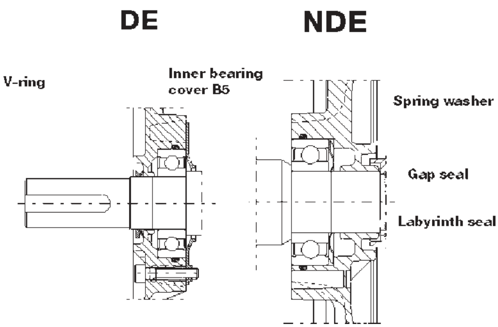
5.3 Bearings

Bearing design for aluminum motors

Motor size	DE	NDE	Roller bearing option	Locked at
56	62-2Z series	62-2Z series	no	D
63	62-2Z series	62-2Z series	no	D
71	62-2Z series	62-2Z series	no	D
80	62-2Z series	62-2Z series	no	D
90	62-2Z series	62-2Z series	no	D
100	63-2Z series	62-2Z series	no	D
112	62-2Z series	62-2Z series	no	D
132	62-2Z series	62-2Z series	no	D
160	63-2Z series	62-2Z series	yes	D
180	63-2Z series	62-2Z series	yes	D
200	63 series	62 series	yes	NDE
225	63 series	62 series	yes	NDE
250	63 series	62 series	yes	NDE
280				

Bearing design for steel and cast iron motors

Motor size	DE	NDE	Roller bearing option	Locked at
71	62-2RS series	62-2RS series	no	D
80	62-2RS series	62-2RS series	no	D
90	62-2RS series	62-2RSseries	no	D
100	62-2RS series	62-2RS series	no	D
112	62-2RS series	62-2RS series	no	D
132	62-2RS series	62-2RS series	no	D
160	63-Z series	63-Z series	yes	D
180	63-Z series	63-Z series	yes	D
200	63-Z series	63-Zseries	yes	D
225	63-Z series	63-Z series	yes	D
250	63-Z series	63-Z series	yes	D
280, 2 pole	6316/C3	6316/C3	yes	D
280, 4-12 pole	6316/C3	6316/C3		
315, 2 pole	6316/C3	6316/C43	yes	D
315, 4-12 pole	6319/C3	6316/C3		
355, 2 pole	6316M/C3	6316M/C3	yes	D
355, 4-12 pole	6322/C3	6316-C3		
400, 2 pole	6317M/C3	6317M/C3	yes	D
400, 4-12 pole	6324/C3	6319-C3		
450, 2 pole	6317 M/C3	6317 M/C3	yes	D
450, 4-12 pole	6326/C3	6322/C3		



Bearings in standard Motors
Bearing Arrangements in aluminum motors, sizes 112-132

5.4 Balancing

Vibration is expressed in mm/s, rms, measured under no load with the motor on elastic mountings. The requirements apply across the measuring range 10 to 1000 Hz.

5.4 Balancing

ABB motors will be as standard balanced according to Grade A.

Vibration grade	Speed range	Maximum relative shaft displacement	Maximum combined mechanical and electrical run-out
	min^{-1}	µm	µm
A	> 1800	65	16
	≤ 1800	90	23
B	> 1800	50	12.5
	≤ 1800	65	16

Note 1 Machines with vibration grade ”B” are specified for high speed drives in critical installations.

Note 2 The maximum relative shaft displacement limits include the run-out. For the definition of the run-out see ISO 7919-1.

5.5 Surface treatment

Special attention is paid to the finish of ABB motors. Screws, steel, aluminum alloy and cast iron parts are treated by the appropriate method for each material. This ensures reliable anti-corrosion protection under the most severe environmental conditions.

The finish coat is blue, Munsel color code 8B 4.5/3.25. It is also designated NCS 4822B05G. The standard finish is moisture and tropic proof in accordance with DIN 50016. It is suitable for outdoor installations, including chemical works.

Surface treatment of steel and cast iron motors

Motor size	Surface treatment	Paint specification
71-132	Two-pack polyurethane paint > 60 µm	Color definition: Munsell blue 8B, 4.5/3.25/NCS 4822 B05G
160-450	Two-pack epoxy paint > 70 µm	Color definition: Munsell blue 8B, 4.5/3.25/NCS 4822 B05G

Surface treatment of aluminum motors

Motor size	Surface treatment	Paint specification
56-80	Epoxy polyester powder paint > 30 µm	Color definition: Munsell blue 8B, 4.5/3.25/NCS 4822 B05G
90-100	Polyester powder paint > 30 µm	Color definition: Munsell blue 8B, 4.5/3.25/NCS 4822 B05G
112-280	Polyester powder paint > 50 µm	Color definition: Munsell blue 8B, 4.5/3.25/NCS 4822 B05G

6

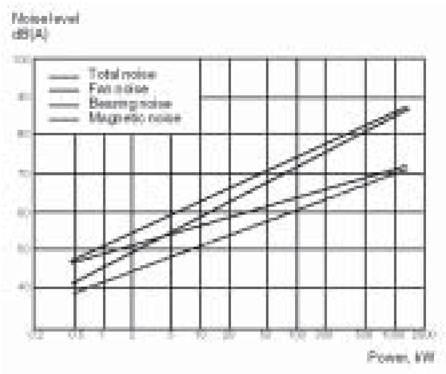
Noise

6.1 Noise reduction

Noise is subject to strict regulations today, with maximum permitted levels. Accordingly, we make noise reduction a major design criterion in the development of our motors.

6.2 Noise components

The principal noise components in a motor are the fan and the magnetic circuit. At high speeds and high outputs, the noise of the fan dominates. At low speeds, the magnetic circuit dominates. In slip-ring motors, the brushes and slip-rings also add noise.



Components that raise noise level

6.2.1 Fan

Fan noise can be reduced by an optimized fan design. Similarly, increasing the overall efficiency of the motor enables the fan diameter to be reduced. However, the fan must be large enough to generate sufficient air flow to ensure adequate cooling of the motor.

The noise level of larger motors can be reduced by fitting a silencer. On larger 2 pole motors, an unidirectional fan which rotates in one direction only and so generates less noise, can be used.

ABB can advise you on the best solution for your specific application.

6.2.2 Magnetic noise

ABB Motors' new electrical design reduces magnetic noise.

6.3 Airborne and structure borne noise

Noise can be propagated in two ways. Airborne noise caused by the fan is propagated by air. Structure borne noise is caused by the bearings, and by magnetic noise vibrating through the motor frame, foundation, walls and any pipework.

6.3.1 Airborne noise

Depending on the application, airborne noise can be reduced by fitting a silencer, a unidirectional fan or by installing a water cooled motor. For instance, choosing an air-water cooled version has a far lower noise level at high outputs and is far cheaper than a totally enclosed air-air cooled version. A totally enclosed version with separate cooling air supply and exhaust usually has the same noise level as a water cooled version, and costs even less. And as larger motors are often installed in separate rooms, the noise level is of secondary importance.

6.3.2 Structure borne noise

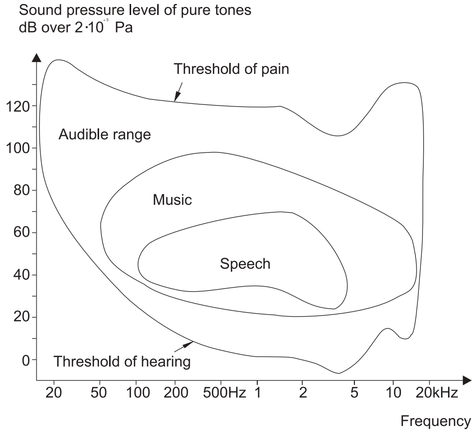
An effective method of eliminating structure borne noise is to mount accurately dimensioned vibration dampers. Choosing vibration dampers arbitrarily, could, however, worsen the noise problem.

6.3.3 Low noise motors

Most manufacturers offer low noise versions of large motors and motors for high speeds. However to achieve low noise, the motor design is modified in ways which may impair cooling. In certain cases, a larger motor may be necessary to deliver the required output, and so increase the cost. The cost of a low noise motor should therefore be weighed against the cost of other noise reducing measures that can be applied to the plant.

6.4 Sound pressure level and sound power level

Sound is pressure waves sent out by an object through the medium (usually air) in which it is immersed. The sound pressure is measured in dB during a noise test. The difference between the sound pressure detectable by the human ear, and the human pain threshold is 1:10,000,000. As the difference in pressure is so great and we experience a 10 dB difference as a doubling of the sound level, a logarithmic scale is employed where:



sound pressure level $Lp = 10 \log (P/P_0)^2$ dB

$P_0 = 2 * 10 - 5$ (Pa) minimum detectable noise
P = measured pressure (Pa)

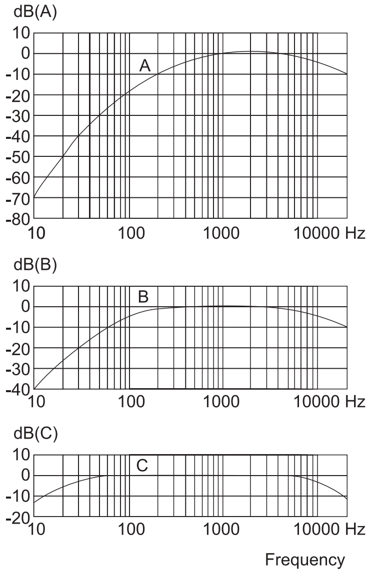
6.4 Sound pressure level and sound power level

The sound pressure is measured in a test room to eliminate reflected noise and external sources. A microphone is variously placed 1 meter from the motor to measure sound from different directions. As the noise level varies in different directions due to the influence of the sources, a tolerance of 3 dB (A) is applicable for the average sound pressure level.

The measured sound level (Lp) can be converted into power radiated from the sound source, to determine the sound power level (Lw). The formula for this is: Lw = Lp + Ls (Ls is calculated from the measuring surface, acc to DIN).

6.5 Weighting filters

Amplifiers and various filters are used when measuring the composite sound. The dB figures measured in this way have (A), (B), or (C) added after them, depending on which filter is used. Normally only the dB (A) figure is given. This corresponds most closely with the perception of the ear.



The filters pass the entire frequency range, but attenuate or amplify certain parts of it. The filter characteristics correspond to stylized 40-, 70- and 100-phon curves for pure tones.

Information on sound pressure level is meaningful only if the distance from the sound source is stated. For example, 80 dB(A) at a distance of one meter from a point sound source corresponds to 70 dB(A) at three meters.

6.6 Octave bands

The mean sound pressure level is measured with a broad band filter covering the entire frequency band. Measurement is also done with a narrow band filter to define

6.6 Octave bands

the noise level per octave band (frequency band), as the perception of the human ear is dependent on the octave band.

Octave band analysis

To get an idea of the character of the composite sound, it has proven practical to divide up the frequency range into octave bands with a ratio of 1:2 between the band limit frequencies. The frequency range is usually referred to by the mid-frequency of the band. The measured dB figures for all octave bands, the octave band levels, are generally shown in the form of an octave band diagram.

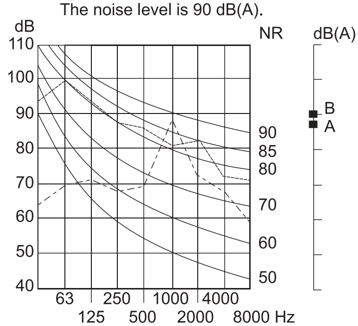
A system of noise rating curves, known as NR curves, has been developed under ISO to express the subjective degree of disturbance of different noises. These curves are intended to be used when assessing the risk of damage to hearing. Similar systems are also available. NR curve numbers signify the degree of noise.

For the octave band with a mid-frequency of 1,000 Hz, the number is equal to the sound pressure level in dB. The NR curve that touches the noise curve of the motor in question determines the motor's noise rating. The table below illustrates the use of noise rating. It shows how long a person can remain in a noisy environment without suffering permanent hearing damage.

NR	Time per day
85	> 5 hours
90	= 5 hours
95	= 2 hours
105	< 20 minutes
120	< 5 minutes

A ------ No risk of hearing damage. The NR 85 curve touches the noise curve of the motor. The noise level is 88 dB(A).

B - - - - Risk of hearing damage. The NR 88 curve touches the noise curve of the motor. The noise level is 90 dB(A).



6.7 Converter duty

At converter duty, the motor noise produced in certain octave bands can change considerably, depending on the switching frequency of the converter. The converter does not produce a sinusoidal voltage.
However, as ABB Direct Torque Control converters do not have a fixed switching frequency, the noise level is much lower than would be the case if a fixed switching frequency converter were used with the same motor.

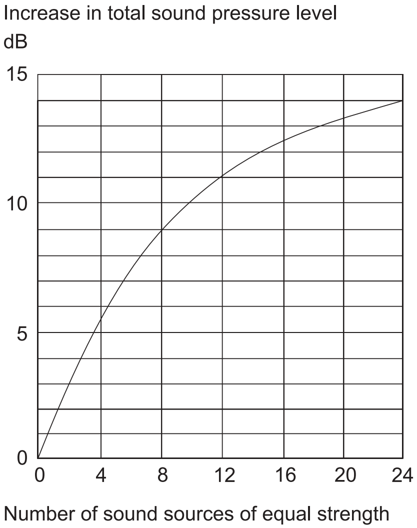
6.8 Additional sound sources

6.8.1 Perception of difference in sound level

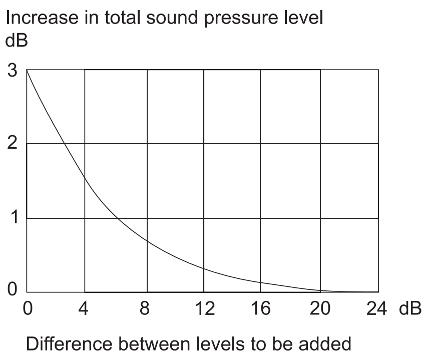
A difference of 1 dB in sound level is barely detectable, whereas a 10 dB difference is perceived as a doubling or halving of the sound level.

The table (position) illustrates the sound pressure level when several sources of sound are present. For example, diagram A shows that the sound pressure level will be 3 dB higher if the sound level of two identical sources are added together. Diagram B shows how the sound level pressure changes when the sound sources have different pressure levels.

However, before logarithmic values can be added or subtracted, they must be converted into absolute numbers. An easier way of adding or subtracting sound sources is to use the diagrams below.



Adding several equal sound sources. Adding together two such sources increases the total level by 3 dB; adding together four increases it by 6 dB, and so on.



Adding two different levels. When the difference between the two sound pressure levels is greater than 10 dB, the lower level contributes so little to the total sound pressure level it may be disregarded.

6.9 Sound pressure levels

Sound pressure level at 50 Hz net duty
Aluminum and steel motors

2 poles frame size	dB(A)	4 poles frame size	dB(A)	6 poles frame size	dB(A)	8 poles frame size	dB(A)
56	48	56	36	56	-	56	-
63	48	63	37	63	-	63	32
71	55	71	45	71	36	71	39
80	58	80	48	80	43	80	44
90	63	90	50	90	44	90	43
100	68	100	54	100	49	100	46
112	63	112	56	112	54	112	52
132	69	132	60	132	61	132	56
160	69	160	62	160	59	160	59
180	69	180	62	180	59	180	59
200	72	200	63	200	63	200	60
225	74	225	66	225	63	225	63
250	75	250	67	250	63	250	63
280	77	280	68	280	66	280	65
315	80	315	71	315	68	315	66
355	83	355	80	355	75	355	75
400	85	400	85	400	80	400	80

Sound pressure level at 50 Hz net duty
Cast iron motors

2 poles frame size	dB(A)	4 poles frame size	dB(A)	6 poles frame size	dB(A)	8 poles frame size	dB(A)
71	57	71	45	71	47	71	-
80	58	80	46	80	48	80	-
90	61	90	52	90	48	90	-
100	65	100	53	100	51	100	-
112	68	112	56	112	54	112	-
132	73	132	60	132	59	132	-
160	70	160	66	160	66	160	73
180	72	180	66	180	68	180	65
200	74	200	66	200	73	200	71
225	74	225	68	225	67	225	73
250	75	250	68	250	68	250	68
280	77	280	68	280	66	280	65
315	78	315	70	315	70	315	72
355	83	355	78	355	75	355	75
400	82	400	78	400	76	400	71
450	85	450	85	450	81	450	82

7

Installation and maintenance

7.1 Delivery acceptance

Please note every motor must be installed and maintained in accordance with the Machine Instructions booklet which is included with the motor on delivery. The installation and maintenance instructions in this chapter are for guideline purposes only.

1. Please inspect equipment for transit damage on delivery, and if found, inform the forwarding agent immediately.

2. Check all rating plate data, especially the voltage and winding connection (Y or Δ).

3. Remove transit locking, if fitted, and turn shaft by hand to check for free rotation.

7.2 Insulation resistance check

Before commissioning the motor, or when winding dampness is suspected, measure the insulation resistance.

Resistance, measured at 25º C, shall exceed the reference value, i.e. 10 M ohm (measured with 500 V dc Megger)

WARNING

Windings should be discharged immediately after measuring to avoid risk of electric shock.

The insulation resistance reference value is halved for each 20º C rise in ambient temperature.

If the reference resistance value is not attained, the winding is too damp, and must be oven dried at 90º C for 12-16 hours, followed by 105º C for 6-8 hours. NB Drain hole plugs, if fitted must always be removed before oven drying.

If the dampness is caused by sea water, the winding should be rewound.

7.3 Torque on terminals

Tightening torque for steel screws and nuts

Thread	4,60 Nm	5,8 Nm	8,8 Nm	10,9 Nm	12,9 Nm
M2,5	0,26				
M3	0,46				
M5	2	4	6	9	10
M6	3	6	11	15	17
M8	8	15	25	32	50
M10	19	32	48	62	80
M12	32	55	80	101	135
M14	48	82	125	170	210
M16	70	125	190	260	315
M20	125	230	350	490	590
M22	160	300	480	640	770
M24	200	390	590	820	1000
M27	360	610	900	1360	1630
M30	480	810	1290	1820	2200
M33	670				
M36	895				

This is a guide only. Frame material and surface treatment effect the tightening torque.

7.4 Usage

Operating conditions

Motors are designed for use in industrial drive applications.
Normal ambient temperature range -25º C to + 40º C.
Maximum altitude 1,000 m above sea level.

Safety

All motors must be installed and operated by qualified personnel familiar with all relevant safety requirements. Safety, and accident prevention equipment required by local health and safety regulations must always be provided at the mounting and operating site.

WARNING

Small motors with supply current directly switched by thermally sensitive switches can start automatically.

Accident prevention

Never stand on a motor. To prevent burns, the outer casing must never be touched during operation. Special instructions may also apply to certain special motor applications (e.g. frequency converter supply). Always use lifting lugs to lift the motor.

7.5 Handling

Storage

- Motors should always be stored in a dry, vibration free and dust free environment.
- Unprotected machined surfaces (shaft-ends and flanges) should be treated with an anti-corrosive.
- It is recommended that shafts are periodically rotated by hand to prevent grease migration.
- Anti condensation heaters, if fitted, should preferably be energized. The characteristics of electrolytic capacitors, if fitted to single-phase motors, will require “reforming” if stored over 12 months.

Please contact ABB Motors office for details.

Transportation

Machines fitted with cylindrical-roller and/or angular-contact bearings must be secured with locking devices during transit.

Machine weights

The total weight of machines with the same frame size can vary depending on output, mounting arrangement and add-on special details.

More accurate weight data can be found on the rating plate of each motor.

7.6 Foundations

Customers are responsible for preparing the foundation for the motor.

The foundation must be smooth, level and, if possible, vibration free. A concrete foundation is therefore recommended. If a metal foundation is used, this should be treated with an anti-corrosive.

The foundation must be stable enough to withstand the forces that can arise in the event of a three-phase short-circuit. Short-circuit torque is primarily a damped sinusoidal oscillation, and can thus have both positive and negative values. The stress on the foundation can be calculated with the aid of the data tables in the motor catalog and the formula below.

$$F = 0.5 \times g \times m + \frac{4 \times T_{max}}{A}$$

where F = stress per side, N

g = gravitational acceleration, 9.81 ms^2

m = weight of motor, kg

T_{max} = maximum torque, Nm

A = lateral distance between the holes in the motor feet, m.

The dimension is taken from the dimension drawing and is expressed in meters.

The foundation should be dimensioned to afford a sufficiently large resonance gap between the natural frequency of the installation and many interference frequencies.

7.6.1 Foundation studs

The motor should be secured with foundation studs or a base plate. Motors for belt drives should be mounted on slide rails.

The foundation studs are bolted to the feet of the motor once the locating pins have been inserted in the holes reamed for the purpose. The studs must be fitted to the right feet with a 1-2 mm shim between the stud and the feet; see the markings on the studs and on the stator feet. Place the motor on the foundation and align

7.6.1 Foundation studs

the coupling. With a spirit level check that the shaft is horizontal. The height of the stator frame can be adjusted with either setting screws or shims. When you are quite sure alignment is correct, grout the blocks.

7.7 Coupling alignment

Motors must always be aligned accurately. This is particularly important in the case of directly coupled motors. Incorrect alignment can lead to bearing failure, vibration, and even shaft fracture. In the event of bearing failure or if vibration is detected, the alignment should be checked immediately.

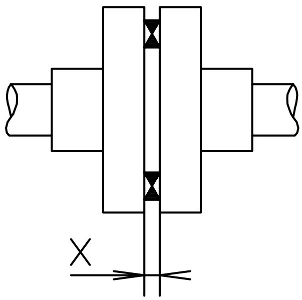
The best way of achieving proper alignment is to mount a pair of dial gauges as shown (page 100). Each gauge is on a coupling half, and they indicate the difference between the coupling halves both axially and radially. Slowly rotating the shafts while observing the gauge readings, gives an indication of the adjustments that need to be made. The coupling halves must be loosely bolted together so that they can easily follow each other when they are turned.

To determine whether the shafts are parallel, measure with a feeler gauge the distance x between the outer edges of the coupling halves at a point on the periphery: see page 100. Then turn both halves together through 90°, without changing the relative positions of the shafts, and measure again at exactly the same point. Measure the distance again after 180° and 270° rotation. For typical coupling sizes, the difference between the highest and lowest readings must not exceed 0.05 mm.

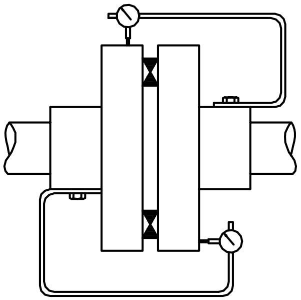
To check that the shaft centres are directly opposite each other, place a steel rule parallel with the shafts on the turned periphery of one coupling half and then measure the clearance between the periphery of the other half and the rule in four positions as a parallelism check. The difference between the highest and lowest readings must not exceed 0.05 mm.

7.7 Coupling alignment

When aligning a motor with a machine whose frame reaches a different temperature to the motor in normal service, allowance must be made for the difference in shaft height resulting from different thermal expansion. For the motor, the increase in height is about 0.03 % from ambient temperature to operating temperature at full output. Mounting instructions from manufacturers of pumps, gear units etc. often state the vertical and lateral displacement of the shaft at operating temperature. It is important to bear in mind this information to avoid vibration and other problems in service.



Checking angular deviation.

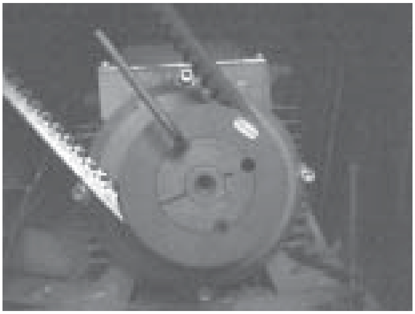


Using dial gauges for alignment.

7.7.1 Mounting pulleys and coupling halves

Care must be taken when fitting pulleys and coupling halves to prevent damage to bearings. They must never be forced into place or levered out.

A coupling half or pulley that is a push fit on the shaft can be pushed on by hand for about half the length of the shaft extension. A special tool or fully-threaded bolt, a nut and two flat pieces of metal, are then used to push it fully home against the shoulder of the shaft.



Mounting a pulley with a fully-threaded bolt, a nut and two flat pieces of metal.

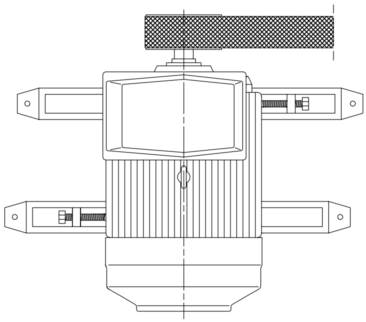
7.8 Slide rails

Motors for belt drives should be mounted on slide rails as shown in figure 2. The slide rails should be placed horizontally on the same level. Then position the motor and slide rails on the foundation and align them such that the middle of the motor pulley coincides with the middle of the pulley on the driven machine. Check the motor shaft is parallel with the drive shaft, and tension the belt in accordance with supplier instructions. Do not exceed the maximum belt forces (i.e. radial bearing loads) stated in the product catalog. The slide rail nearest the belt must be positioned such that the tensioning screw is between the motor and the driven machine. The screw in the other slide rail must be on the other side. See figure.

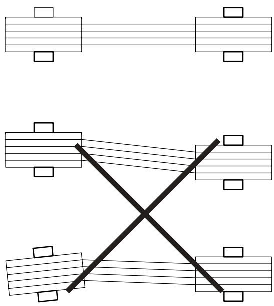
After alignment, grout in the slide rail fixing bolts.

WARNING

Do not over-tension the belts. Excessive belt tension can damage bearings and cause shaft fracture.



Positions of slide rails for belt drive.



With belt drive the shafts must be parallel and the pulleys must be in line.

7.9 Mounting bearings

Always take special care with bearings. Bearings should be fitted by heating or purpose made tools, and removed with pullers.

When a bearing is to be mounted on a shaft, cold or hot mounting may be used. Cold mounting is only suitable for small bearings and bearings that do not have to be pressed far on to the shaft. For hot mounting and where the bearing is an interference fit on the shaft, the bearing is first heated in an oil bath or with a special heater. It is then pressed onto the shaft with a mounting sleeve that fits the inner ring of the bearing. Grease-filled bearings, which usually have sealing plates or shield plates, should not be heated.

7.10 Lubrication

ABB policy is to have reliability as a vital issue in bearing design as well as in bearing lubrication systems. That is why we, as standard, follow the L1-principle (meaning that 99 per cent of the motors are sure to make the interval time). The lubrication intervals can also be calculated according to L10-policy which means that 90 per cent of the motors are sure to make the interval time. L 10-values, which are normally doubled compared to L1-values, are available from ABB offices at request.

7.10.1 Motors with permanently greased bearings

Motors up to frame size 180 are normally fitted with permanently greased bearings of type Z or 2Z.

Guidelines for bearing lifetime:

- 4 pole motors, 20,000 - 40,000 duty hours[1])
- 2 and 2/4 pole motors, 10,000 - 20,000 duty hours[1])
- The shorter intervals apply to larger motors.

[1]) depending on application and load conditions

7.10.2 Motors with lubrication system

Lubricate the motor when operational. If a grease outlet plug is fitted, temporarily remove when lubricating, or permanently with auto lubrication. If the motor is fitted with a lubrication plate, use values given, else use the values accoding to L1 -principle, following on the next page:

7.10 Lubrication

The following general lubrication table follows the L1-principle, which is the ABB standard for all low voltage motors.

Lubrication intervals and amounts

Frame size	Amount of grease g/bearing	3600 r/min	3000 r/min	1800 r/min	1500 r/min	1000 r/min	500-900 r/min
	Ball bearings						
	Lubrication intervals in duty hours						
112	10	10000	13000	18000	21000	25000	28000
132	15	9000	11000	17000	19000	23000	26500
160	25	7000	9500	14000	17000	21000	24000
180	30	6000	8000	13500	16000	20000	23000
200	40	4000	6000	11000	13000	17000	21000
225	50	3000	5000	10000	12500	16500	20000
250	60	2500	4000	9000	11500	15000	18000
280	1)	2000	3500	8000	10500	14000	17000
315	1)	2000	3500	6500	8500	12500	16000
355	1)	1200	2000	4200	6000	10000	13000
400	1)	1200	2000	4200	6000	10000	13000
400 M3BP	1)	1000	1600	2800	4600	8400	12000
450	1)	1000	1600	2400	4000	8000	8800
	Roller bearings						
	Lubrication intervals in duty hours						
160	25	3500	4500	7000	8500	10500	12000
180	30	3000	4000	7000	8000	10000	11500
200	40	2000	3000	5500	6500	8500	10500
225	50	1500	2500	5000	6000	8000	10000
250	60	1300	2200	4500	5700	7500	9000
280	1)	1000	1800	4000	5300	7000	8500
315	1)	1000	1800	3300	4300	6000	8000
355	1)	600	1000	2000	3000	5000	6500
400	1)	600	1000	2000	3000	5000	6500
400 M3BP	1)	500	800	1400	2300	4200	6000
450	1)	500	800	1200	2000	4000	4400

1) Please check the correct amounts from the Manual.

More detailed information is available in the Manual, available at abb.com/motors&drives, or from any ABB office.

7.10 Lubrication

The tables are prepared for horizontally mounted motors. Halve table values for vertically mounted motors. If the motor is fitted with a lubrication information plate, values in that plate should be followed. More detailed information can be found in the Manual from ABB.

7.11 Fuse rating guide

Fuse rating guide

Direct on line

Max Motor FL Amps	Recommended standard fuse	Recommended Motor circuit fuselink ref.
0.5	2	-
1	4	-
1.6	6	-
3.5	6	-
6	16	-
8	20	-
10	25	20M25
14	32	20M32
17	40	32M40
23	50	32M50
30	63	32M63
40	80	63M80
57	100	63M100
73	125	100M125
95	160	100M160
100	200	100M200
125	200	-
160	250	200M250
195	315	200M315
225	355	315M400
260	400	315M400
315	450	400M500

8

The SI system

8.1 Quantities and units

This section explains some of those units in the SI (Syst‘eme International d’Unités) system of units that are used in conjuction with electric motors and their application.

A distinction is made between quantity, quantity value, unit, measurement number and between the name and symbol of a unit. These distinctions are explained by the following example:

Example:

	Name	Symbol
Quantity	power	P
Unit	watt	W

P = 5.4 W, i.e. the power is 5.4 watts
Measurement number = 5.4
Symbol for unit = W
Name of unit = watt
Symbol for quantity = P
Name of quantity = power
Value of quantity = 5.4 watts

8.1 Quantities and units

Quantity		Unit		
Name	**Symbol**	**Name**	**Symbol**	**Remarks**
Space and time				
Plane angle	α β γ	Radian	rad	
		Degree	…°	1° = π/180 rad
		Minute	…’	
		Second	…”	
Length	l	Meter	m	
Area	A	Square meter	m^2	
Volume	V	Cubic meter	m^3	
		Litre	l	
Time	t	Second	s	
		Minute	min	
		Hour	h	
Frequency	f	Hertz	Hz	
Velocity	v	Meter per second	m/s	km/h is the commonest multiple
Acceleration	a	Meter per second squared	m/s^2	
Free fall acceleration	g	Meter per second squared	m/s^2	
Energy				
Active	W	Joule	J	1 J = 1 Ws = 1 Nm
Watt second	Ws			
Watt hour	Wh			
Reactive	Wq	Var second	vars	
		Var hour	varh	
Apparent	Ws	Volt-ampere second	VAs	
		Volt-ampere hour	VAh	
Power				
Active	P	Watt	W	1kW =1.34 hp[1]) = 102 kpm/s = 10^3 Nm/s = 10^3J/s
Reactive	Q, P_q	Var	var	
Apparent	S, P_s	Volt-ampere	VA	

[1]) 1 kW = 1.34 hp (UK, US) is used in IEC Publ 72

1 kW = 1.36 hp (metric horsepower)

8.1 Quantities and units

Quantity	Unit			
Name	**Symbol**	**Name**	**Symbol**	**Remarks**
Mechanical				
Mass	m	Kilogram	kg	
		Tonne	t	
Density	ρ	Kilogram per cubic meter	kg/m^3	
Force	F	Newton	N	1 N = 0.105 kp
Moment of force	M	Newton-meter	Nm	1 Nm = 0.105 kpm = 1 Ws
Moment of inertia	J	Kilogram-meter	kgm^2	$J = \frac{G \times D^2}{4}$
Pressure	p	Pascal	Pa	$1 \text{ Pa} = 1 \text{ N/m}^2$
		Newton per square meter	N/m^2	$1 \text{ N/m2} = 0.102 \text{ kp/m}^2 = 10^{-5} \text{ bar}$
		Bar	bar	$1 \text{ bar} = 10^5 \text{ N/m}^2$
Heat				
Thermodynamic temperature	T, θ	Kelvin	K	Old name: absolute temperature
Celsius temperature	ϑ, t	Degree Celsius	°C	0 °C = 273.15 K
Temperature difference	Δ T, Δ ϑ	Kelvin	K	The intervall 1 K is identical to the interval 1 ° C
		Degree Celsius	° C	
Thermal energy	Q	Joule	J	
Electricity				
Electric potential	V	Volt	V	1 V = 1 W/A
Electric voltage	U	Volt	V	
Electric current	I	Ampere	A	
Capacitance	C	Farad	F	1 F = 1 C/V
Reactance	X	Ohm	Ω	
Resistance	R	Ohm	Ω	1 Ω = 1 V/A
Impedance	Z	Ohm	Ω	$Z = \sqrt{R^2+X^2}$

Prefixes for multiples:
Multiples of SI units are indicated by the following prefixes. The use of prefixes in brackets should be restricted.

10^3	kilo	k
(10^2)	(hecto)	(h)
(10^1)	(deca)	(da)
(10^{-1})	(deci)	(d)
(10^{-2})	(centi)	(c)
10^{-3}	milli	m
10^{-6}	micro	µ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a

8.2 Conversion factors

The units normally used for technical applications are SI units.

However, other units may be encountered in descriptions, drawings, etc., especially where the inch system is involved.

Note that the US gallon and the UK gallon are not the same.
To avoid confusion it is advisable to put US or UK after the unit.

Length

1 nm = 1.852 km	1 km = 0.540 nm
1 mile = 1.609344 km	1 km = 0.621 mile
1 yd = 0.9144 m	1 m = 1.09 yd
1 ft = 0.3048 m	1 m = 3.28 ft
1 in = 25.4 mm	1 mm = 0.039 in

Velocity

1 knot = 1.852 km/h	1 km/h = 0.540 knot
1 m/s = 3.6 km/h	1 km/h = 0.278 m/s
1 mile/h = 1.61 km/h	1 km/h = 0.622 mile/h

Area

1 acre = 0.405 ha	1 ha = 2.471 acre
1 ft^2 = 0.0929 m^2	1 m^2 = 10.8 ft^2
1 in^2 = 6.45 cm^2	1 cm^2 = 0.155 in^2

Volume

1ft^3 = 0.0283 m^3	1 m^3 = 36.3 ft^3
1 in^3 = 16.4 cm^3	1 cm^3 = 0.0610 in^3
1 gallon (UK) = 4.55 l	1 l = 0.220 gallon (UK)
1 gallon (US) =3.79 l	1 l = 0.264 gallon (US)
1 pint = 0.568 l	1 l = 1.76 pint

Flow

1 m^3/h = 0.278 x 10^{-3} m^3/s	1 m^3/s = 3600 m^3/h
1 cfm = 0.472 x 10^{-3} m^3/s	1 m^3/s = 2120 cfm

Mass

1 lb = 0.454 kg	1 kg = 2.20 lb
1 oz = 28.3 g	1 g = 0.0352 oz

Force

1 kp = 9.80665 N	1 N = 0.105 kp
1 lbf = 4.45 N	1 N = 0.225 lbf

Pressure

1 mm vp = 9.81 Pa	1 Pa = 0.102 mm vp
1 kp/cm^2 = 98.0665 kPa	1 kPa = 0.0102 kp/cm^2
1 kp/cm^2 = 0.980665 bar	1 bar = 1.02 kp/m^2
1 atm = 101.325 kPa	1 kPa = 0.00987 atm
1 lbf/in^2 = 6.89 kPa	1 kPa = 0.145 lbf/in^2

Energy

1 kpm = 9.80665 J	1 J = 0.102 kpm
1 cal = 4.1868 J	1 J = 0.239 cal
1 kWh = 3.6 MJ	1 MJ = 0.278 kWh

Power

1 hp = 0.736 kW	1 kW = 1.36 hp
1 hp (UK, US) = 0.746 kW	1 kW = 1.34 hp (UK, US)
1 kcal/h = 1.16 W	1 W = 0.860 kcal/h

Temperature

0 °C	=	32 °F
°C	=	5/9 (°F - 32)
0 °F	=	-17.8 °C
°F	=	9/5 (°C + 32)

Comparison table for temperatures

° F	° C
0	-17.8
10	-12.2
20	-6.7
30	-1.1
32	0
40	4.4
50	9.9
60	15.5
70	21.0
80	23.6
90	32.1
100	37.8

9

Selecting a motor

9.1 Motor type

The two fundamental variables to consider when selecting a motor are:

- The electricity supply to which the motor will be connected
- The type of enclosure or housing

Type of enclosure

There are two basic enclosure options available: drip proof in steel or totally enclosed, in aluminum, steel and cast iron.

The totally enclosed fan cooled (TEFC) motor is the predominant standard for industrial applications today. The versatile TEFC is fully enclosed within the motor frame, with cooling air directed over it by an externally mounted fan.

List ABB motors:

€ Standard three phase motors
• IEC and NEMA
• Hazardous area motors
• Marine motors
• Open drip proof motors
• Single phase motors
• Brake motors
• Integral motors
• Windmill generators
• Water cooled motors
• Roller table motors
• Fan application motors
• Smoke venting motors
• High speed motors
• Traction motors
• Reluctance motors

9.2 Loading (kW)

Loading is determined by the equipment to be driven, and the torque available at the shaft.

Electric motors have standard outputs per frame size.

9.3 Speed

The induction motor is a fixed single speed machine. Its speed is dependent on the frequency of the electricity supply and the stator winding design.

9.3 Speed

No load speed is slightly lower than synchronous speed due to the no load losses in the machine. Full load speed is typically a further 3-4 per cent lower than no load speed.

Synchronous Speed r/min	=	Frequency X 120 / Number of poles (Stator winding)

Motor speeds

	50 Hz speed r/min		60 Hz speed r/min	
Number of poles	**Synchronous**	**Typical full load**	**Synchronous**	**Typical full load**
2	3.000	2.900	3.600	3.450
4	1.500	1.440	1.800	1.740
6	1.000	960	1.200	1.150
8	750	720	900	850
10	600	580	720	700
12	500	480	600	580
16	375	360	450	430

9.4 Mounting

The mounting position must always be given when ordering.

9.5 Power supply

The supply voltage and frequency must be given when ordering

9.6 Operating environment

The environment in which the motor is to operate is an important factor to consider when ordering, as the ambient temperature, humidity and altitude can all affect performance.

9.7 Ordering check list

Check List

Safe area TEFC Motor Fixed Speed

Supply ☐ **Volts** ☐ **Ph** ☐ **Hz**
Rating ☐ **kW**
Speed ☐ **r/min** ☐ **Pole**
Duty ☐ ☐ **Mounting IM**

Drive ☐ **Direct** ☐ **Belt**

Insulation/Temp rise ☐ / ☐

Torque type ☐ **Quadratic** ☐ **Constant**

Environmental conditions
IP ☐ **Ambient** ☐ ☐ **Relative Humidity**

Check List

Safe area TEFC Motor Variable Speed

Supply ☐ **Volts** ☐ **Ph** ☐ **Hz**
Rating ☐ **kW**
Speed ☐ **r/min** ☐ **Pole**
Duty ☐ ☐ **Mounting IM**

Drive ☐ **Direct** ☐ **Belt**

Insulation/Temp rise ☐ / ☐

Torque type ☐ **Quadratic** ☐ **Constant**

Environmental conditions
IP ☐ **Ambient** ☐ ☐ **Relative Humidity**

VSD
Type of controller **DTC** **PWM**
Speed Range ☐ **Max** ☐ **Min**
Abs Power (kW) ☐ **Max** ☐ **Min**
Output Filters (du/dt) ☐ **Fitted** ☐ **Not fitted**
Max cable length (Metres) ☐

10

Variable speed drives

10.1 General

Squirrel cage induction motors offer excellent availability, reliability and efficiency. However, they have two weaknesses; starting performance and smooth speed control over a wide range. A motor with a frequency converter - variable speed drive (VSD) - solves both these problems. A variable speed drive motor can be started softly with low starting current, and the speed can be controlled and adjusted to suit the application demand without steps over a wide range.

The benefits of variable speed drives have been widely recognized and the number of different applications equipped with VSD is growing. Depending on the motor size, the share of VSD can be even 50% of the new installations.

The principal advantages of VSD:

- Optimal speed and control accuracy to deliver major energy and environmental savings
- Reduced need for maintenance
- Higher production quality and greater productivity.

10.2 Converters

Converters are power electronic devices which convert input AC power at fixed voltage and frequency into output electric power with variable voltage and frequency. Direct or indirect converters are used, depending on the solution employed.

10.2.1 Direct converters

Direct converters such as cyclo-converters and matrix converters change the input directly to output with no intermediate links. Cyclo-converters are used in high power applications (MW range) and at low frequencies.

10.2.2 Indirect converters

Indirect converters are either current source, or voltage source converters.

In a voltage source converter (VSC), the intermediate link acts as a dc-voltage source and the output consists of controlled voltage pulses at continuously variable frequency which are fed to different phases of the three-phase system. This enables stepless speed control of the motor.

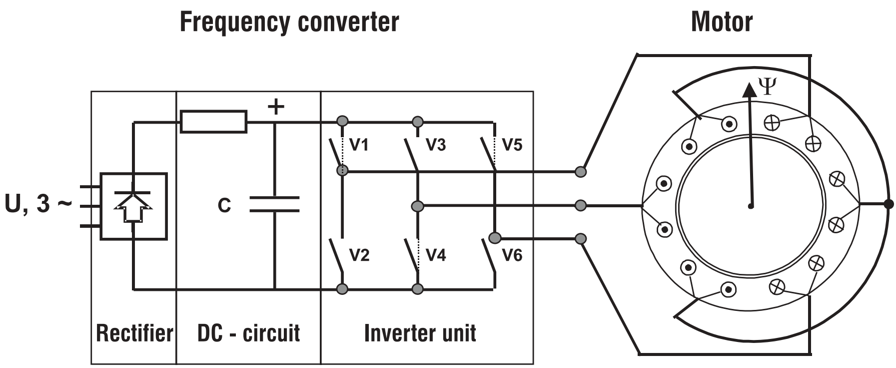
In a current source converter (CSC), the dc-link acts as a dc-current source and the output is a current pulse, or current pulse sequence.

10.3 Pulse Width Modulation (PWM)

ABB variable speed drives use Pulse Width Modulated (PWM) with variable switching frequency voltage source converters as these best meet the majority of requirements.

In a PWM drive, the rectifier converts the input line power which has a nominally fixed voltage and frequency to fixed voltage dc power. This fixed voltage dc power is then filtered to reduce the ripple voltage resulting from the rectification of the ac line. The inverter then changes the fixed voltage dc power to ac output power with adjustable voltage and frequency.

10.4 Dimensioning the drive



A complete dimensioning program for drives and motors can be downloaded from www.abb.com/motors&drives, or is available on a CD. Below here is a brief information about motor and converter selection.

Motor selection

The actual load torque should be below the guideline of the selected motor and converter combination (see Figure on page 125). However, if the operation will not be continuous in all speed range duty points, the load curve may exceed the guideline. In which case, special dimensioning is required.

Further, the maximum torque of the motor must be at least 40 per cent higher than the load torque at any frequency, and the maximum permissible speed of the motor must not be exceeded.

Motor design

Converters with different working principles, modulation patterns and switching frequencies give different performances for the same motor. As performance and behavior is also dependent on the motor design and construction, motors of the same size and output power but of different design, may behave quite differently with the same converter and thus the selection and dimensioning instructions are product specific.

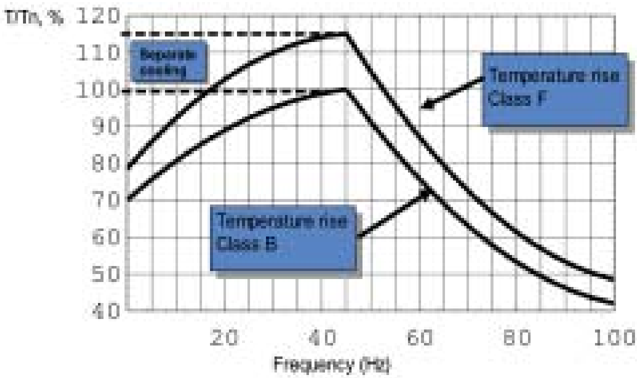
10.4 Dimensioning the drive

Converter selection

The converter should be selected according to the nominal power P_N and the rated current of the motor. Sufficient current margin should be reserved for controlling and managing the dynamic situations.

10.5 Loadability (torque)

Both theoretical calculations and laboratory tests show that the continuous maximum load (torque) of a converter driven motor is mainly dependent on the modulation pattern and switching frequency of the converter, but is also dependent on the motor design. The tables below offer guidelines for motor selection.



Motor loadability with ABB's DTC-controlled frequency converters. Guideline curve for ABB standard induction motors.

These guidelines present the maximum continuous load torque of a motor as a function of frequency (speed) to give the same temperature rise as with rated sinusoidal voltage supply at nominal frequency and full rated load.

The temperature rise of ABB motors is usually according to class B. Standard motors, but not the hazardous area motors, can in such cases be dimensioned either according to the Temperature rise class B curve, or Temperature rise class F curve, which provides higher loadability. If the ABB product catalogue indicates that class F temperature rise is utilized on sinusoidal supply, the motor can only be dimensioned according to the Temperature rise class B curve.

ABB motors (IP 55 or higher) can be used with frequency converters as follows:

- Process performance cast iron and aluminum motors for demanding industrial applications
- General purpose aluminum and cast iron motors for general applications
- Hazardous area motors: flameproof, non-sparking and dust ignition proof motors
- For standard pump and fan applications, standard steel motors (IP55) and

10.5 Loadability (torque)

open drip proof motors (IP23) can be used.

The output torque of the frequency converter driven motors is usually slightly reduced due to extra heating from harmonics and a decrease in cooling according to frequency range. However, the loadability of the motor can be improved by:

■ More effective cooling

More effective cooling is achieved by mounting a separate constant speed cooling fan, which is especially beneficial at low speeds. Selecting a fan motor speed and fan design to deliver a higher cooling effect than that of the standard motor at nominal speed, will give an improved cooling effect over the entire speed range.

Liquid cooling (water cooled motors) is another very effective cooling method. In very demanding cases, the bearing end shields must also be cooled.

■ Filtering

Filtering the converter output voltage reduces the harmonic content of the motor voltage and current and thus reduces generation of additional losses in the motor. This minimizes the need for derating. The full power of the drive and the speed range must be taken into account when dimensioning filters (additional reactances). Filters also reduce electromagnetic noise, EMC and voltage peak problems. However they do limit the maximum torque of the motor.

■ Special rotor design

Special rotors are seldom needed with modern frequency converters, but with older types special rotors are most probably needed with motors bigger than frame size 355.

A motor with a rotor cage and rotor bars specifically designed for VSD performs well in a converter drive but is usually not the optimal solution for DOL applications.

10.6 Insulation level

In a frequency converter, the output voltage (or current) most often is a voltage (current) pulse or pattern of pulses. Depending on the type of power components and the design of power circuit, a considerable overshoot is developed at the voltage pulse leading edge. The winding insulation level must, therefore, always be checked using product specific instructions. The basic rules for standard applications are:

- If the nominal voltage of the supply network is up to 500 V, no insulation strengthening is required for standard ABB induction motors
- If the nominal network voltage is higher than 500 V, but not more that 600 V, reinforced motor insulation or du/dt-filters are recommended
- If the nominal network voltage is higher than 600 V, but not more that 690 V, reinforced motor insulation and du/dt-filters are recommended

Exact product specific instructions can be found from ABB product catalogues.

10.7 Earthing

In a converter drive special attention must be paid to the earthing arrangements to ensure:

- Proper action of all protective devices and relays for general safety
- Minimum or acceptable level of electromagnetic interference
- Acceptable level of bearing voltages to avoid bearing currents and bearing failures

10.8 High speed operation

In a frequency converter drive the actual speed of the motor may deviate considerably from its rated speed. For higher speed operation, the maximum permissible speed of the motor type - or critical speed of the entire equipment must not be exceeded.

Guideline values for the maximum speeds of standard motors:

Frame size	Speed r/min
71-100	6000
112-200	4500
225-280	3600
315, 2-pole	3600
315, other pole numbers	2300
355, 2-pole	3000
355, other pole numbers	2000
400, 2-pole	3600
400, other pole numbers	1800
450, 2-pole	3600
450, other pole numbers	1800

When high speed operation exceeds the nominal speed of the motor, the maximum torque and bearing construction should also be checked.

10.8.1 Maximum torque

In the field weakening area, the voltage of the motor is constant, but the motor flux and the capability to produce torque reduces rapidly when the frequency is increased. At the highest speed point (or at any other duty point in the field weakening area), the maximum (breakdown) torque must be not less than 40 per cent higher than the load torque.

If filters or additional reactances are used between the converter and the motor, the voltage drop of the fundamental voltage with full load current must be taken into account.

10.8.2 Bearing construction

There is a limit to the speed at which rolling bearings can be operated. Bearing type and size, internal design, load, lubrication and cooling conditions, plus cage design, accuracy and internal clearance, all influence the permissible maximum speed.

10.8.3 Lubrication

In general, the limit is set by the operating temperature with respect to the lubricant and bearing component. Changing the bearings and/or lubricant may enable higher speeds. However, if this is done, the combination should be checked by ABB.

10.8.3 Lubrication

The sheer strength of the lubricant is determined by its base oil viscosity and thickener, which, in turn, determines the permissible operating speed for the particular bearing. The maximum speed can be increased by using high speed greases or oil lubrication. Very accurate lubrication with small quantities also reduces the bearing friction and heat generation.

10.8.4 Fan noise

Fan noise increases with the speed of the motor and generally becomes dominant at 50 Hz for 2- and 4-pole motors. If the motor speed further increases, the noise level will also be higher. The noise level increase can be calculated approximately using the following formula:

$$\Delta \text{Lsp} = 60 \times \log \frac{n_2}{n_1} \text{dB (A)}$$

where Δ Lsp = increase of the sound pressure level when the speed is changed from n1 to n2.

Fan noise is typically 'white noise', i.e. containing all frequencies within the audible frequency range.

Fan noise can be reduced by either:

- Replacing the fan (and fan cover) with a reduced outer diameter fan
- Using a unidirectional fan
- Fitting a silencer

10.9 Balancing

The balancing accuracy and mechanical strength of all rotating parts should be checked if the standard motor speed limit is to be exceeded. All other parts mounted on the motor shaft, such as coupling halves and pulleys must also be carefully balanced.

10.10 Critical speeds

The first critical speed of the whole drive system, or of its components, should not be exceeded, and a safety margin of 25 per cent should be allowed.

However, also supercritical drive systems can be used, but those must be dimensioned case by case.

10.11 Shaft seals

All rubbing shaft seals (V-rings, oil seals, sealed bearings RS, etc.) have a recommended maximum speed limit. If this is below the proposed high speed operation, non-rubbing labyrinth seals should be used.

10.12 Low speed operation

10.12.1 Lubrication

At very low speeds, the motor's ventilation fan loses its cooling capacity. If the operational temperature of the motor bearings is = 80° C, (check by measuring the surface temperature of the bearing endshields), shorter relubrication intervals or special grease (Extreme Pressure (EP) grease or high temperature lubricant) should be used.

The relubrication interval should be halved for each 15° C increase in the bearing temperature above + 70° C.

10.12.2 Cooling capacity

The air flow and cooling capacity depends on the fan speed. A separate constant speed fan can be used to increase cooling capacity and motor loadability at low speeds. As the internal cooling is not affected by an outer separate fan, a small reduction in loadability is still necessary at very low speeds.

10.12.3 Electromagnetic noise

The harmonic components of the frequency converter voltage increase the magnetic noise level of the motor. The frequency range of these magnetic force waves can cause structural resonance in the motor, especially steel frame ones.

Magnetic noise can be reduced by:

- Increasing the switching frequency, giving higher order harmonics and lower amplitudes, less sensitive to the human ear
- Filtering the harmonic components at the converter output filter or in additional reactances
- Motor silencer
- Separate cooling system with 'white' fan noise which masks the magnetic noise.

Global supplier with local presence

Low Voltage Motors

Manufacturing sites (*) and some of the larger sales companies.

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