Standards, formulae, tables

Standards, formulae, tables
Marking of electrical equipment

Marking according to DIN EN 61346-2:2000-12 (IEC 61346-2:2000)

Moeller has decided to apply the above standard over a transitional period.

In contrast to the previously used designation, it is now the function of the electrical apparatus within the circuit that determines its identifying letter. This provides a great deal of freedom in the choice of a device's identifying letter.

Example for a resistor

- Normal current limiter: R
- Heater resistor: E
- Measuring resistor: B

In addition, Moeller has introduced company-specific stipulations for implementing the standard, which deviate from the standard to some extent.

- The marking of connection terminals are **not** readable from the right.
- A second code letter for the marking of the use of the equipment is **not** given, e. g.: timer relay K1T becomes K1.
- Circuit-breakers with the main function of protection are still marked with Q. They are numbered from 1 to 10 from the top left.
- Contactors are newly marked with Q and numbered from 11 to nn. e. g.: K91M becomes Q21.
- Relays remain K and are numbered from 1 to n.

The marking appears in a suitable position as close as possible to the circuit symbol. The marking forms the link between the equipment in the installations and the various circuit documents (wiring diagrams, parts lists, circuit diagrams, instructions). To simplify maintenance, the marking can also be applied in full or in part on or near to the equipment.

Selected equipment with a comparison of the Moeller used code letters old – new → table, page 10-3.

Standards, formulae, tables
Marking of electrical equipment

Code letter old	Example for electrical equipment	Code letter new
B	Measuring transducer	T
C	Capacitors	C
D	Memory device	C
E	Electro filter	V
F	Bimetal release	F
F	Pressure switches	B
F	Fuses (fine, HH, signal fuse)	F
G	Frequency inverters	T
G	Generators	G
G	Soft starters	Q
G	UPS	G
H	Lamps	E
H	Optical and acoustic indicators	P
H	Signal lamps	P
K	Auxiliary relays	K
K	Relay	K
K	Semiconductor contactors	Q
K	Contactor	Q
K	Timing relays	K
L	Reactor coil	R
M	Motor	M
N	Buffer amplifier, inverting amplifier	T
P	Meters	P

Standards, formulae, tables
Marking of electrical equipment

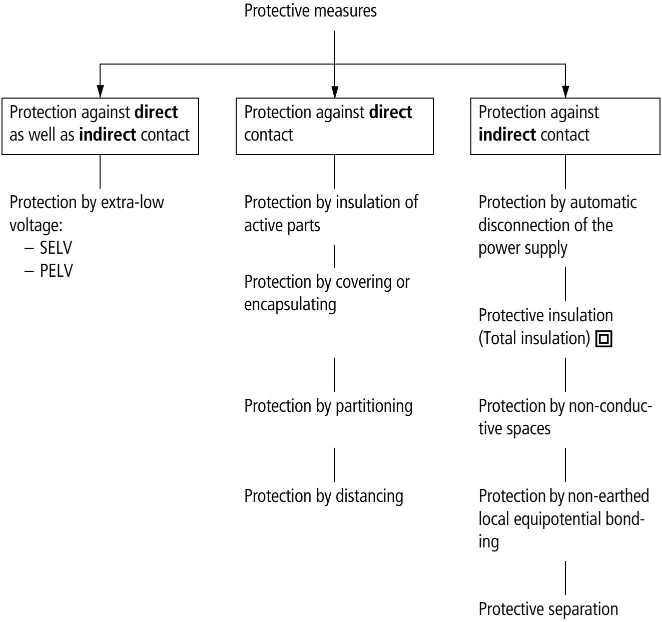
Code letter old	Example for electrical equipment	Code letter new
Q	Switch-disconnector	Q
Q	Circuit-breaker for protection	Q
Q	Motor-protective circuit-breakers	Q
Q	Star-delta switches	Q
Q	Disconnectors	Q
R	Variable resistor	R
R	Measurement resistor	B
R	Heating resistor	E
S	Control circuit devices	S
S	Pushbutton actuators	S
S	Position switches	B
S	Switches	S
T	Voltage transformers	T
T	Current transformer	T
T	Transformers	T
U	Frequency converter	T
V	Diodes	R
V	Rectifier	T
V	Transistors	K
Z	EMC filter	K
Z	Suppressors and arc quenching devices	F

Standards, formulae, tables
Protective measures

Protection against electrical shock to IEC 364-4-41/VDE 0100 Part 410

A distinction is drawn here between protection against direct contact, protection against indirect contact and protection against both direct and indirect contact.

- **Protection against direct contact**
  These are all the measures for the protection of personnel and working animals from dangers which may arise from contact with live parts of electrical equipment.
- **Protection against indirect contact**
  This is the protection of personnel and working animals from dangers which may arise from accidental contact with components or extraneous conductive parts.



Protection must be ensured by either a) the equipment itself or b) the use of protective measures when erecting the installation or c) a combination of a) and b).

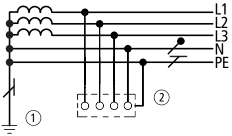
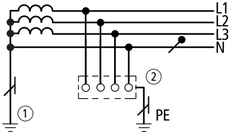
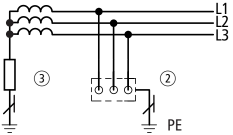
Standards, formulae, tables

Protective measures

Protection against indirect contact by means of disconnection or indication

The conditions for disconnection are determined by the type of system in use and the protective device selected.

Systems to IEC 364-3/VDE 0100 Part 310

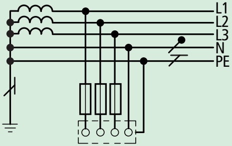
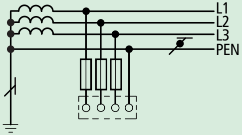
Earth continuity type systems	Meaning of designation
TN system 	T: Direct earthing of a point (system earth) N:Chassis directly connected to the system earth
TT system 	T: Direct earthing of a point (system earth) T: Chassis directly earthed, independent of the earthing of the power supply (system earth)
IT network 	I: All live parts isolated from earth or one point connected to earth via an impedance T: Chassis directly earthed, independent of the earthing of the power supply (system earth)

① System earth
② Chassis
③ Impedance

Standards, formulae, tables

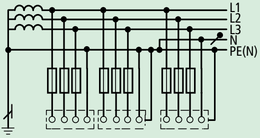
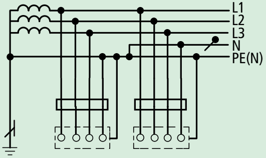
Protective measures

Protective devices and conditions for disconnection to IEC 364-4-1/VDE 0100 Part 410

Type of distribution system	**TN system**		
Protection with	Circuit principle	Description so far	Condition for disconnection
Overcurrent protective device	TN-S system separated neutral and earth conductors throughout the system 		$Z_s \times I_a \leqq U_0$ Z_s = Impedance of the fault circuit I_a = current, which causes disconnection in: • $\leqq$ 5 s • $\leqq$ 0.2 s in circuits up to 35 A with sockets and hand-held components which can be moved U_0 = rated voltage against earthed conductor
Fuses Miniature circuit-breakers Circuit-breakers	TN-C system Neutral conductor and protection functions are combined throughout the system in a single PEN conductor. 	Protective multiple earthing	

Standards, formulae, tables
Protective measures

Protective devices and conditions for disconnection to IEC 364-4-1/VDE 0100 Part 410

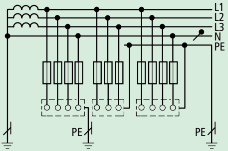
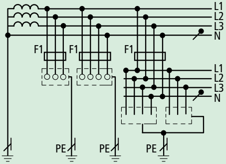
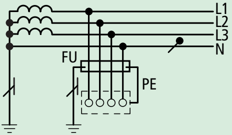
Type of distribution system	**TN system**		
Protection with	Circuit principle	Description so far	Condition for disconnection
Overcurrent protective device	TN-C-S system Neutral conductor and protection functions are in a part of the system combined in a single PEN conductor 		
Residual-current protective device		Residual-current protective circuit	$Z_s \times I_{\Delta n} \leqq U_0$ $I_{\Delta n}$ = Rated fault current U_0 = Maximum permissible touch voltage*: ($\leqq$ 50 V AC, $\leqq$ 120 V DC)
Residual voltage protection device (in special case)			
Insulation monitoring device			

* → table, page 10-12

Standards, formulae, tables

Protective measures

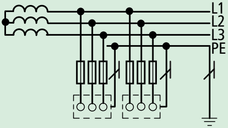
Protective devices and conditions for disconnection to IEC 364-4-1/VDE 0100 Part 410

Type of distribution system	**TT system**		
Protection with	Circuit principle	Description so far	Conditions for indication/disconnection
Overcurrent protective device Fuses Miniature circuit-breakers Circuit-breakers		Protective earth	$R_A \times I_a \leqq U_L$ R_A = Earthing resistance of conductive parts of the chassis I_a = Current which causes automatic disconnection in $\leqq$ 5 s U_L = Maximum permissible touch voltage*: ($\leqq$ 50 V AC, $\leqq$ 120 V DC)
Residual-current protective device		Residual-current protective circuit	$R_A \times I_{\Delta n} \leqq U_L$ $I_{\Delta n}$ = Rated fault current
Residual-voltage protective device (for special cases)		Residual-voltage protective circuit	R_A: max. 200 Ω

* → table, page 10-12

Standards, formulae, tables
Protective measures

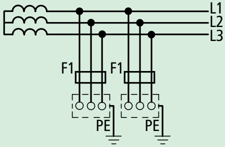
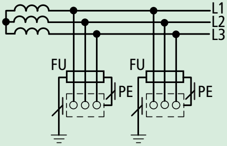
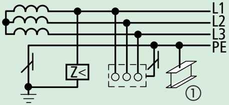
Protective devices and conditions for disconnection to IEC 364-4-1/VDE 0100 Part 410

Type of distribution system	**TT system**		
Protection with	Circuit principle	Description so far	Conditions for indication/disconnection
Insulation monitoring device	–		
Overcurrent protective device		Feed back to protective multiple earthing	$R_A \times I_d \leqq U_L$ (1) $Z_S \times I_a \leqq U_o$ (2) R_A = Earthing resistance of all conductive parts connected to an earth I_d = Fault current in the event of the first fault with a negligible impedance between a phase conductor and the protective conductor or element connected to it U_L = Maximum permissible touch voltage*: $\leqq$ 50 V AC, $\leqq$ 120 V DC

* → table, page 10-12

Standards, formulae, tables
Protective measures

Protective devices and conditions for disconnection to IEC 364-4-1/VDE 0100 Part 410

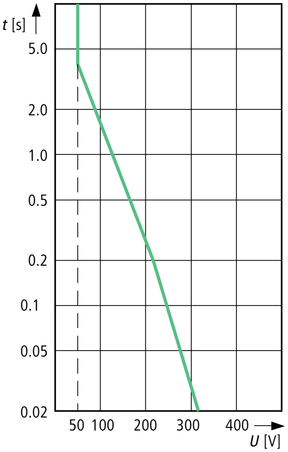
Type of distribution system	IT network		
Protection with	Circuit principle	Description so far	Conditions for indication/disconnection
Residual current protective device		Residual-current protective circuit	$R_A \times I_{\Delta n} \leqq U_L$ $I_{\Delta n}$ = Rated fault current
Residual voltage protective device (for special cases)		Residual-voltage protective circuit	R_A: max. 200 Ω
Insulation monitoring device	 ① additional potential equalisation	Protective-conductor system	$R \times I_a \leqq U_L$ R = Resistance between components and extraneous conductive parts which can be touched simultaneously

* → table, page 10-12

Standards, formulae, tables
Protective measures

The protective device must automatically disconnect the faulty part of the installation. At no part of the installation must there be a touch voltage or an effective duration greater than that specified in the table below. The internationally agreed limit voltage at a maximum disconnect time of 5 s is 50 V AC or 120 V DC.

Maximum permissible effective duration dependent on touch voltage to IEC 364-4-41



Anticipated touch voltage		Max. permissible disconnection time
AC $_{eff}$ [V]	DC $_{eff}$ [V]	[s]
< 50	< 120	•
50	**120**	**5.0**
75	140	1.0
90	160	0.5
110	**175**	**0.2**
150	200	0.1
220	250	0.05
280	310	0.03

10

Standards, formulae, tables

Overcurrent protection of cables and conductors

Overcurrent protective devices must be used to protect cable and conductors against excessive warming, which may result both from operational overloading and from short-circuit.

Overload protection

Overload protection means providing protective devices which will interrupt overload currents in the conductors of a circuit before they can cause temperature rises which may damage the conductor insulation, the terminals and connections or the area around the conductors.

For the protection of conductors against overload the following conditions must be fulfilled (source: DIN VDE 0100-430)

$I_B \leqq I_n \leqq I_Z$

$I_2 \leqq 1{,}45\, I_Z$

I_B Anticipated operating current of the circuit

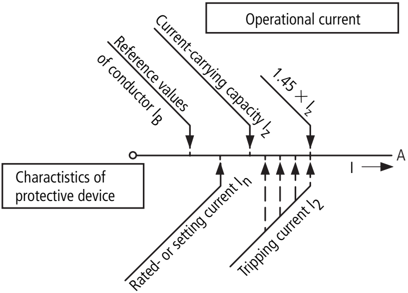
I_Z Current carrying capacity of conductor or cable

I_n Rated current of protective device

Note:

For adjustable protective devices, In corresponds to the value set.

I_2 The current which causes tripping of the protective device under the conditions specified in the equipment regulations (high test current).



Arrangement of protection devices for overload protection

Protection devices for overload protection must be fitted at the start of every circuit and at every point where the current-carrying capacity is reduced unless an upstream protection device can ensure protection.

Standards, formulae, tables

Overcurrent protection of cables and conductors

Note:

Reasons for the current-carrying capacity being reduced:

Reduction of the conductor cross-section, a different installation method, different conductor insulation, a different number of conductors.

Protective devices for overload protection must not be fitted if interruption of the circuit could prove hazardous. The circuits must be laid out in such a way that no possibility of overload currents occurring need be considered.

Examples:

- Energizing circuits for rotating machines
- Feeder circuits of solenoids
- Secondary circuits of current transformers
- Circuits for safety purposes

Short-circuit protection

Short-circuit protection means providing protective devices which will interrupt short-circuit currents in the conductors of a circuit before they can cause a temperature rise which may damage the conductor insulation, the terminals and connections, or the area around the cables and conductors.

In general, the permissible disconnection time *t* for short circuits of up to 5 s duration can be specified approximately using the following equation:

$$t = \left(k \times \frac{S}{I}\right)^2 \quad \text{or} \quad I^2 \times t = k^2 \times S^2$$

The meaning of the symbols is as follows:

t: Permissible disconnection time in the event of short-circuit in s

S: Conductor cross-section in mm²

I: Current in the cast of short-circuit in A

k: Constants with the values

- 115 for PVC-insulated copper conductors
- 74 for PVC-insulated aluminium conductors
- 135 for rubber-insulated copper conductors
- 87 for rubber-insulated aluminium conductors
- 115 for soft-solder connections in copper conductors

With very short permissible disconnection times (< 0,1 s) the product from the equation $k^2 \times S^2$ must be greater than the $I^2 \times t$ value of the current-limiting device stated by manufacturer.

Note:

This condition is met provided that there is a cable protective fuse up to 63 A rated current present and the smallest cable cross-section to be protected is at least 1.5 mm² Cu.

Arrangement of protective devices for protection in the event of a short-circuit.
Protective devices for protection in the event of a short-circuit must be fitted at the start of every circuit and at every point at which the short-circuit current-carrying capacity is reduced unless a protective device fitted upstream can ensure the necessary protection in the event of a short circuit.

Standards, formulae, tables
Overcurrent protection of cables and conductors

Note:

Causes for the reduction in the short-circuit current-carrying capacity can be: Reduction of the conductor cross-section, other conductor insulation.

Short-circuit protection must not be provided where an interruption of the circuit could prove hazardous.

Protection of the phase conductors and the neutral conductor

Protection of the phase conductors

Overcurrent protection devices must be provided in every phase conductor: they must disconnect the conductor in which the overcurrent occurs, but not necessarily also disconnect the other live conductors.

Note:

Where the disconnection of an individual phase conductor could prove hazardous, as for example, with three-phase motors, suitable precautions must be taken. Motor-protective circuit-breakers and circuit-breakers disconnect in three poles as standard.

Protection of the neutral conductor:

1. In installations with directly earthed neutral point **(TN or TT systems)**

Where the cross-section of the neutral conductor is less than that of the phase conductors, an overcurrent monitoring device appropriate to its cross-section is to be provided in the neutral conductor; this overcurrent monitoring device must result in the disconnection of the phase conductors but not necessarily that of the neutral conductor.

An overcurrent monitoring device is not necessary where:

- the neutral conductor is protected in the event of a short circuit by the protective device for the phase conductors
- the largest current which can flow through the neutral conductor is, in normal operation, considerably less than the current-carrying capacity of this conductor.

Note:

This second condition is met provided that the power transferred is divided as evenly as possible among the phase conductors, for example where the total power consumption of the load connected between phase and neutral conductors, lamps and sockets is much less than the total power transferred via the circuit. The cross-section of the neutral conductor must not be less than the values in the table on the next page.

2. In installations without a directly earthed neutral point **(IT system)**

Where it is necessary for the neutral conductor to be included, an overcurrent monitoring device must be provided in the neutral conductor of each circuit, to cause disconnection of all live conductors in the relevant circuit (including the neutral conductor).

The overcurrent monitoring device may however be omitted where the neutral conductor in question is protected against short circuit by an upstream protective device, such as in the incoming section of the installation.

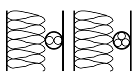
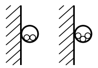
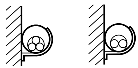
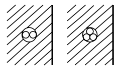
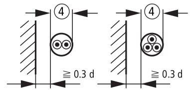
Disconnection of the neutral conductor

Where disconnection of the neutral conductor is specified, the protective device used must be designed in such a way that the neutral conductor cannot under any circumstances be disconnected before the phase conductors and reconnected again after them. 4-pole NZM circuit-breakers always meet these conditions.

Standards, formulae, tables

Overcurrent protection of cables and conductors

Current-carrying capacity and protection of cables and conductors with PVC insulation to DIN VDE 0298-4, at 25 °C ambient temperature

Type of cable or conductor	NYM, NYBUY, NHYRUZY, NYIF, H07V-U, H07V-R, H07V-K, NYIFY				NYY, NYCWY, NYKY, NYM, NYMZ, NYMT, NYBUY, NHYRUZY
Type of installation	A1	B1	B2	C	E
			On or under the wall surface, under plaster		
	In heat-insulating walls, in conduit under the surface	In electrical conduit or cable channel			
		Single-core cable	Multi-core cable	Direct installation	exposed
					
	Multi-core cable under the surface	Single wires in conduit on the wall surface	Multi-core cable in conduit on the wall surface or on the floor	Multi-core cable Spur wiring in the wall or under plaster	
Number of cores	2 3	2 3	2 3	2 3	2 3
	Current-carrying capacity I_z in A for 25 C ambient temperature and 70 C operating temperature. For the allocation of overcurrent protective devices apply the following conditions $I_b \leqq I_n \leqq I_z$ and $I_2 \leqq 1.45\ I_z$ t. For overcurrent protection devices with a tripping current of $I_2 \leqq I_n$ only apply the condition:		$I_b \leqq I_n \leqq I_z$ (I_b: Operating current of the circuit). Circuit-breakers and switch-disconnectors fulfil this condition. For overcurrent protective devices with other tripping currents, only the following condition applies: $I_n \leqq \frac{1,45}{x} \cdot I_n ; = \frac{I_z}{I_n}$		

Standards, formulae, tables

Overcurrent protection of cables and conductors

Continue

Type of installation	A1				B1				B2				C				E			
Number of cores	2		3		2		3		2		3		2		3		2		3	
Copper conductor cross-section in mm²	I_z	I_n	I_z	I_n	I_z	I_n	I_z	I_n	I_z	I_n	I_z	I_n	I_z	I_n	I_z	I_n	I_z	I_n	I_z	I_n
1.5	16.5	16	14	13	18.5	16	16.5	16	16.5	16	15	13	21	20	18.5	16	21	20	19.5	16
2.5	21	20	19	16	25	25	22	20	22	20	20	20	28	25	25	25	29	25	27	25
4	28	25	25	25	34	32	30	25	30	25	28	25	37	35	35	35	39	35	36	35
6	36	35	33	32	43	40	38	35	39	35	35	35	49	40	43	40	51	50	46	40
10	49	40	45	40	60	50	53	50	53	50	50	50	67	63	63	63	70	63	64	63
16	65	63	59	50	81	80	72	63	72	63	65	63	90	80	81	80	94	80	85	80
25	85	80	77	63	107	100	94	80	95	80	82	80	119	100	102	100	125	125	107	100
35	105	100	94	80	133	125	118	100	117	100	101	100	146	125	126	125	154	125	134	125
50	126	125	114	100	160	160	142	125	–	–	–	–	–	–	–	–	–	–	–	–
70	160	160	144	125	204	200	181	160	–	–	–	–	–	–	–	–	–	–	–	–
95	193	160	174	160	246	200	219	200	–	–	–	–	–	–	–	–	–	–	–	–
120	223	200	199	160	285	250	253	250	–	–	–	–	–	–	–	–	–	–	–	–

For overcurrent protective devices whose rated current In does not conform to the values given in the table, select the next lower available rated current value.

10

Standards, formulae, tables

Overcurrent protection of cables and conductors

Minimum cross section for protective conductors to DIN VDE 0100-510 (1987-06, t), DIN VDE 0100-540 (1991-11)

		Protective conductor or PEN		Protective conductor[3] laid		
Phase conductors		Insulated power cables	0,6/1-kV cable with 4 conductors	Protected		Unprotected[2]
mm^2		mm^2	mm^2	mm^2 Cu	Al	mm^2 Cu
up to	0.5	0.5	–	2.5	4	4
	0.75	0.75	–	2.5	4	4
	1	1	–	2.5	4	4
	1.5	1.5	1.5	2.5	4	4
	2.5	2.5	2.5	2.5	4	4
	4	4	4	4	4	4
	6	6	6	6	6	6
	10	10	10	10	10	10
	16	16	16	16	16	16
	25	16	16	16	16	16
	35	16	16	16	16	16
	50	25	25	25	25	25
	70	35	35	35	35	35
	95	50	50	50	50	50
	120	70	70	70	70	70
	150	70	70	70	70	70
	185	95	95	95	95	95
	240	–	120	120	120	120
	300	–	150	150	150	150
	400	–	185	185	185	185

[1] PEN conductor ≧ 10 mm^2 Cu or 18 mm^2 Al.

[2] It is not permissible to lay aluminium conductors without protection.

[3] With phase conductors of ≧ 95 mm^2 or more, it is advisable to use non-insulted conductors

Standards, formulae, tables

Overcurrent protection of cables and conductors

Conversion factors

When the ambient temperature is not 30 °C; to be used for the current-carrying capacity of wiring or cables in air to VDE 0298 Part 4.

Insulation material[1)]	NR/SR	PVC	EPR
Permissible operational temperature	60 °C	70 °C	80 °C
Ambient temperature °C	Conversion factors		
10	1.29	1.22	1.18
15	1.22	1.17	1.14
20	1.15	1.12	1.10
25	1.08	1.06	1.05
30	1.00	1.00	1.00
35	0.91	0.94	0.95
40	0.82	0.87	0.89
45	0.71	0.79	0.84
50	0.58	0.71	0.77
55	0.41	0.61	0.71
60	–	0.50	0.63
65	–	–	0.55
70	–	–	0.45

1) Higher ambient temperatures in accordance with information given by the manufacturer

Standards, formulae, tables

Overcurrent protection of cables and conductors

Converstion factors to VDE 0298 part 4

Grouping of several circuits

	Arrangement	Number of circuits								
		1	2	3	4	6	9	12	15 16	20
1	Embedded or enclosed	1.00	0.80	0.70	0.70 0.65	0.55 0.57	0.50	0.45	0.40 0.41	0.40 0.38
2	Fixed to walls or floors	1.00	0.85	0.80 0.79	0.75	0.70 0.72	0.70	–	–	–
3	Fixed to ceilings	0.95	0.80 0.81	0.70 0.72	0.70 0.68	0.65 0.64	0.60 0.61	–	–	–
4	Fixed to cable trays arranged horizontally or vertically	1.00	0.97 0.90	0.87 0.80	0.77 0.75	0.73 0.75	0.72 0.70	–	–	–
5	Fixed to cable trays or consoles	1.00	0.84 0.85	0.83 0.80	0.81 0.80	0.79 0.80	0.78 0.80	–	–	–

Standards, formulae, tables

Electrically critical equipment of machines

Extract from IEC/EN 60204-1 (VDE 0113 Teil 1)

This world wide binding standard is used for the electrical equipment of machines, provided that for the type of machine to be equipped there is no product standard (Type C).

Safety requirements regarding the protection of personnel, machines and material according to the European Machinery Directive are stressed under the heading "Safety of machines". The degree of possible danger is to estimated by risk assessment (EN 1050). The Standard also includes requirements for equipment, engineering and construction, as well as tests to ensure faultless function and the effectiveness of protective measures.

The following paragraphs are an extract from the Standard.

Mains isolating device (main switches)

Every machine must be equipped with a manually-operated main switch, henceforth referred to as a mains isolating device. It must be possible to isolate the entire electrical equipment of the machine from the mains using the mains isolating device. The breaking capacity must be sufficient to simultaneously disconnect the stalled current of the largest motor in the machine and the total current drawn by all the other loads in normal operation.

Its Off position must be lockable and must not be indicated until the specified clearances and creepage distances between all contacts have been achieved. It must have only one On and one Off position with associated stops. Star-delta, reversing and multi-speed switches are not permissible for use as mains isolating devices.

The tripped position of circuit-breakers is not regarded as a switch position, therefore there is no restriction on their use as mains isolating devices.

Where there are several incomers, each one must have a mains isolating device. Mutual interlocking must be provided where a hazard may result from only one mains isolating device being switched off. Only circuit-breakers may be used as remotely-operated switches. They must be provided with an additional handle and be lockable in the Off position.

Protection against electric shock

The following measures must be taken to protect personnel against electric shock:

Protection against direct contact

This is understood as meaning protection by means of an enclosure which can only be opened by qualified personnel using a key or special tool. Such personnel is not obliged to disable the mains isolating device before opening the enclosure. Live parts must be protected against direct contact in accordance with IEC 50274 or VDE 0660 part 514.

Where the mains isolating device is interlocked with the door, the restrictions mentioned in the previous paragraph cease to apply because the door can only be opened when the mains isolating device is switched off. It is permissible for an interlock to be removable by an electrician using a tool, e.g. in order to search for a fault. Where an interlock has been removed, it must still be possible to switch off the mains isolating device.

Standards, formulae, tables
Electrically critical equipment of machines

Where it is possible for an enclosure to be opened without using a key and without disconnection of the mains isolating device, all live parts must at the very least comply with IP 2X or IP XXB degree of protection in accordance with IEC/EN 60529.

Protection against indirect contact
This involves prevention of a dangerous touch voltage resulting from faulty insulation. To meet this requirement, protective measures in accordance with IEC 60364 or VDE 0100 must be used. An additional measure is the use of protective insulation (protection class II) to IEC/EN 60439-1 or VDE 0660 Part 500.

Protection of equipment

Protection in the event of power failure
When the power returns following a failure in the supply, machines or parts of machines must not start automatically where this would result in a dangerous situation or damage to property. With contactor controls this requirement can easily be met via self-maintaining circuits.

For circuits with two-wire control, an additional contactor relay with three-wire control in the supply to the control circuit can carry out this function. Mains isolating devices and motor-protective circuit-breakers with undervoltage releases also reliably prevent automatic restarting on return of voltage.

Overcurrent protection
No overcurrent protective device is normally required for the mains supply cable. Overcurrent protection is provided by the protective device at the head of the incoming supply. All other circuits must be protected by means of fuses or circuit-breakers.

The stipulation for fuses is that replacement must be freely obtainable in the country in which the fuses are used. This difficulty can be avoided by using circuit-breakers, with the added benefits of disconnection in all poles, rapid operational readiness and prevention of single-phasing.

Overload protection of motors
Continously operating motors above 0.5 kW must be protected against overload. Overload protection is recommended for all other motors. Motors which are frequently starting and braking are difficult to protect and often require a special protective device. Built-in thermal sensors are particularly suitable for motors with restricted cooling. In addition, the fitting of overload relays is always recommended, particularly as protection by stalled rotor.

Standards, formulae, tables

Electrically critical equipment of machines

Control functions in the event of a fault

A fault in the electrical equipment must not result in a dangerous situation or in damage. Suitable measures must be taken to prevent danger from arising. The expense of using appropriate measures can be extremely high if applied generally. To permit a better assessment of the magnitude of the risk in conjunction with the respective application, the standard EN ISO 13849-1 has been published: "Safety-related parts of control systems Part 1: General rules for design".

The use of risk assessment to EN 13849-1 is dealt with in the Moeller manual "Safety Specifications for Machines and Plant" (Order No. TB 0-009).

Emergency-Stop device

Every machine which could potentially cause danger must be equipped with an Emergency-Stop device which, in a main circuit may be an Emergency-Stop switch, and in a control circuit an Emergency-Stop control circuit device.

Actuation of the Emergency-Stop device must result in all current loads which could directly result in danger, being disconnected by de-energization via another device or circuit, i.e. electromechanical devices such as contactors, contactor relays or the undervoltage release of the mains isolating device.

For direct manual operation, Emergency-Stop control circuit devices must have a mushroom-head push-button and positively opening contacts. Once the Emergency-Stop control circuit device has been actuated, it must only be possible to restart the machine after local resetting. Resetting alone must not allow restarting.

Furthermore, the following apply for both Emergency-Stop switch and Emergency control circuit device:

- The handle must be red with a yellow background
- Emergency-Stop devices must be quickly and easily accessible in the event of danger
- The Emergency-Stop function must take precedence over all other functions and operations
- It must be possible to determine functional capability by means of tests, especially in severe environmental conditions.
- Where there is separation into several Emergency-Stop areas, it must be clearly discernible to which area an Emergency-Stop device applies

Emergency operations

The term Emergency-Stop is short and concise, and should continue to be used for general usage.

It is not clear however from the term Emergency-Stop which functions are carried out with this. In order to be able to give a more precise definition here, IEC/EN 60204-1 describes under the generic term "Emergency operations" two specific functions:

1. Emergency-Stop
This involves the possibility of stopping dangerous motions as quickly as possible.

2. Emergency-Off
Where there is a risk of an electric shock by direct contact, e.g. with live parts in electrical operating areas, then an Emergency-Off device shall be provided.

Standards, formulae, tables

Electrically critical equipment of machines

Colours of push-buttons and their meanings

To IEC/EN 60073, VDE 0199, IEC/EN 60204-1
(VDE 0113 Part 1)

Colour	Meaning	Typical application
RED	Emergency	• Emergency-Stop • Fire fighting
YELLOW	Abnormal condition	Intervention, to suppress abnormal conditions or to avoid unwanted changes
GREEN	Normal	Start from safe conditon
BLUE	Enforced action	Resetting function
WHITE	No specific meaning assigned	• Start/ON (preferred) • Stop/OFF
GREY		• Start/ON • Stop/OFF
BLACK		• Start/ON • Stop/Off (preferred)

Standards, formulae, tables

Electrically critical equipment of machines

Colours of indicator lights and their meanings

To IEC/EN 60073, VDE 0199, IEC/EN 60204-1
(VDE 0113 Part 1)

Colour	Meaning	Explanation	Typical application
RED	Emergency	Warning of potential danger or a situation which requires immediate action	• Failure of pressure in the lubricating system • Temperature outside specified (safe) limits • Essential equipment stopped by action of a protective device
YELLOW	Abnormal condition	Impending critical condition	• Temperature (or pressure) different from normal level • Overload, which is permissible for a limited time • Reset
GREEN	Normal	Indication of safe operating conditions or authorization to proceed, clear way	• Cooling liquid circulating • Automatic tank control switched on • Machine ready to be started
BLUE	Enforced action	Operator action essential	• Remove obstacle • Switch over to Advance
WHITE	No specific meaning assigned (neutral)	Every meaning: may be used whenever doubt exists about the applicability of the colours RED, YELLOW or GREEN; or as confirmation	• Motor running • Indication of operating modes

Colours of illuminated push-buttons and their meanings

Both tables are valid for illuminated push-buttons, Table 1 relating to the function of the actuators.

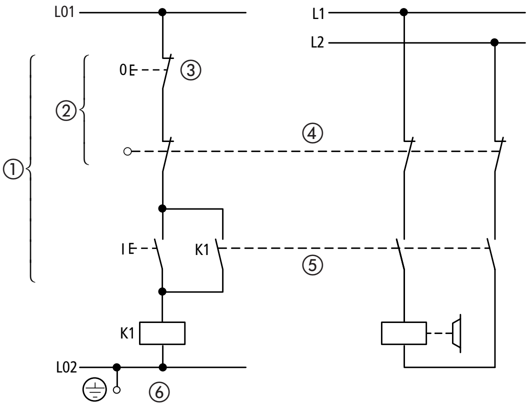
Standards, formulae, tables
Measures for risk reduction

Risk avoidance in a malfunction

A fault in the electrical equipment must not result in a dangerous situation or in damage. Suitable measures must be taken to prevent danger from arising.

The IEC/EN 60204 1 specifies a range of measures which can be taken to reduce danger in the event of a fault.

The use of proven circuits and components



① All switching functions on the non-earthed side

② Use of break devices with positively opening contacts (not to be confused with interlocked opposing contacts)

③ Shut-down by de-excitation (fail-safe in the event of wire breakage)

④ Circuit engineering measures which make undesirable operational states in the event of a fault unlikely (in this instance, simultaneous interruption via contactor and position switch)

⑤ Switching of all live conductors to the device to be controlled

⑥ Chassis earth connection of the control circuit for operational purposes (not used as a protective measure)

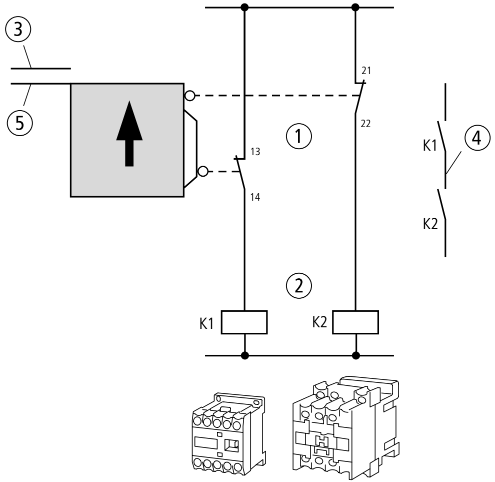
Redundancy

This means the existence of an additional device or system which takes over the function in the event of a fault.

Standards, formulae, tables
Measures for risk reduction

Diversity

The construction of control circuits according to a range of function principles or using various types of device.



1. Functional diversity by combination of N/O and N/C contacts
2. Diversity of devices due to use of various types of device (here, various types of contactor relay)
3. Safety barrier open
4. Feedback circuit
5. Safety barrier closed

Performance tests
The correct functioning of the equipment can be tested either manually or automatically.

Standards, formulae, tables

Degrees of protection for electrical equipment

Degrees of protection for electrical equipment by enclosures, covers and similar to IEC/EN 60529 (VDE 0470 part 1)

The designation to indicate degrees of enclosure protection consists of the characteristic letters IP (Ingress Protection) followed by two characteristic numerals. The first numeral indicates the degree of protection of persons against contact with live parts and of equipment against ingress of solid foreign bodies and dust, the second numeral the degree of protection against the ingress of water.

Protection against contact and foreign bodies

First nu-meral	Degree of protection	
	Description	Explanation
0	Not protected	No special protection of persons against accidental contact with live or moving parts. No protection of the equipment against ingress of solid foreign bodies.
1	Protection against solid objects ≧ 50 mm	Protection against contact with live parts with back of hand. The access probe, sphere 50 mm diameter, must have enough distance from dangerous parts. The probe, sphere 12,5 mm diameter, must not fully penetrate.
2	Protection against solid objects ≧ 12.5 mm	Protection against contact with live parts with a finger. The articulated test finger, 12 mm diameter and 80 mm length, must have suffient distance from dangerous parts. The probe, sphere 12.5 mm diameter, must not fully penetrate.

Standards, formulae, tables

Degrees of protection for electrical equipment

Protection against contact and foreign bodies

First numeral	Degree of protection	
	Description	**Explanation**
3	Protection against solid objects $\geqq$ 2.5 mm	Protection against contact with live parts with a tool. The entry probe, 1.0 mm diameter, must not penetrate. The probe, 2.5 mm diameter, must not penetrate.
4	Protection against solid objects $\geqq$ 1 mm	Protection against contact with live parts with a wire. The entry probe, 1.0 mm diameter, must not penetrate. The probe, 1.0 mm diameter, must not penetrate.
5	Protection against accumulation of dust	Protection against contact with live parts with a wire. The entry probe, 1.0 mm diameter, must not penetrate. The ingress of dust is not totally prevented, but dust does not enter in sufficient quantity to interfere with satisfactory operation of the equipment or with safety.
6	Protection against the ingress of dust Dust-tight	Protection against contact with live parts with a wire. The entry probe, 1.0 mm diameter, must not penetrate. No entry of dust.

Example for stating degree of protection: IP 4 4

Characteristic letter — IP

First numeral — 4

Second numeral — 4

Standards, formulae, tables

Degrees of protection for electrical equipment

Protection against water

Second numeral	Degree of protection	
	Description	Explanation
0	Not protected	No special protection
1	Protected against vertically dripping water	Dripping water (vertically falling drops) shall have no harmful effect.
2	Protected against dripping water when enclosure tilted up to 15?	Dripping water shall have no harmful effect when the enclosure is tilted at any angle up to 15? from the vertical.
3	Protected against sprayed water	Water falling as a spray at any angle up to 60° from the vertical shall have no harmful effect.
4	Protected against splashing water	Water splashed against the enclosure from any direction shall have no harmful effect.
5	Protected against water jets	Water projected by a nozzle against the equipment from any direction shall have no harmful effect.
6	Protected against powerful water jets	Water projected in powerful jets against the enclosure from any direction shall have no harmful effect.
7	Protected against the effects of occasional submersion	Ingress of water in harmful quantities shall not be possible when the enclosure is immersed in water under defined conditions of pressure and time.

Standards, formulae, tables

Degrees of protection for electrical equipment

Second numeral	Degree of protection	
	Description	Explanation
8	Protected against the effects of submersion	Ingress of water in harmful quantities must not be possible when the equipment is continuously submerged in water under conditions which are subject to agreement between manufacturer and user. These conditions must be more stringent than those for characteristic numeral 7.
9K*	Protected during cleaning using high-pressure/steam jets	Water which is directed against the enclosure under extremely high pressure from any direction must not have any harmful effects. Water pressure of 100 bar Water temperature of 80 °C

* This characteristic numeral originates from DIN 40050 9.

Standards, formulae, tables
Degrees of protection for electrical equipment

Type of current	Utilisation catorgory	Typical applications:	Normal conditions of use	
		I = Switch-on current, I_c = Switch-off current, I_e = Rated operational current, U = Voltage, U_e = Rated operational voltage U_r = Recovery voltage, $t_{0,95}$ = Time in ms, until 95 % of the steady-state current has been reached. $P = U_e \times I_e$ = Rated power in Watts	Switch on $\frac{I}{I_e}$	 $\frac{U}{U_e}$
Alternating current	AC-12	Control of resistive and solid state loads as in optocoupler input circuits	1	1
	AC-13	Control of solid state loads with transformer isolation	2	1
	AC-14	Control of small electromagnetic loads (max. 72 VA)	6	1
	AC-15	Control of electromagnetic loads (above 72 VA)	10	1
			$\frac{I}{I_e}$	$\frac{U}{U_e}$
Direct current	DC-12	Control of resistive and solid state loads as in optocoupler input circuits	1	1
	DC-13	Control of electromagnets	1	1
	DC-14	Control of electromagnetic loads with economy resistors in the circuit	10	1

to IEC 60947-5-1, EN 60947-5-1 (VDE 0600 part 200)

10

Standards, formulae, tables

Degrees of protection for electrical equipment

				Abnormal conditions of use					
Switch off				Switch on			Switch off		
$\cos\varphi$	$\frac{I}{I_e}$	$\frac{U}{U_e}$	$\cos\varphi$	$\frac{I}{I_e}$	$\frac{U}{U_e}$	$\cos\varphi$	$\frac{I}{I_e}$	$\frac{U}{U_e}$	$\cos\varphi$
0.9	1	1	0.9	–	–	–	–	–	–
0.65	1	1	0.65	10	1.1	0.65	1.1	1.1	0.65
0.3	1	1	0.3	6	1.1	0.7	6	1.1	0.7
0.3	1	1	0.3	10	1.1	0.3	10	1.1	0.3
$t_{0,95}$	$\frac{I}{I_e}$	$\frac{U}{U_e}$	$T_{0,95}$	$\frac{I}{I_e}$	$\frac{U}{U_e}$	$T_{0,95}$	$\frac{I}{I_e}$	$\frac{U}{U_e}$	$T_{0,95}$
1 ms	1	1	1 ms	–	–	–	–	–	–
$6 \times P$[1)]	1	1	$6 \times P$[1)]	1.1	1.1	$6 \times P$[1)]	1.1	1.1	$6 \times P$[1)]
15 ms	1	1	15 ms	10	1.1	15 ms	10	1.1	15 ms

1) The value "$6 \times P$" results from an empirical relationship that represents most DC magnetic loads to an upper limit of $P = 50$ W, i.e. 6 [ms]/[W] = 300 [ms]. Loads having a power consumption greater than 50 W are assumed to consist of smaller loads in parallel. Therefore, 300 ms is to be an upper limit, irrespective of the power consumption.

Standards, formulae, tables

Utilisation categories for contactors and motor starters

Type of current	Utilisation catorgory	Typical applications: I = Switch-on current, I_c = Switch-off current, I_e = Rated operational current, U = voltage, U_e = Rated operational voltage U_r = Recovery voltage	Verification of electrical lifespan		
			Switch on		
			$\frac{I_e}{A}$	$\frac{I}{I_e}$	$\frac{U}{U_e}$
Alternating current	AC-1	Non-inductive or slightly inductive loads, resistance furnaces	All values	1	1
	AC-2	Slip-ring motors: starting, switch-off	All values	2.5	1
	AC-3	Squirrel-cage motors: stating, switch-off, switch-off during running[4)]	$I_e \leqq 17$ $I_e > 17$	6 6	1 1
	AC-4	Sqirrel-cage motors: starting, plugging, reversing, inching	$I_e \leqq 17$ $I_e > 17$	6 6	1 1
	AC-5A	Switching of electric discharge lamp controls			
	AC-5B	Switching of incandescent lamps			
	AC-6A[3)]	Switching of transformers			
	AC-6B[3)]	Switching of capacitor banks			
	AC-7A	Slightly inductive loads in household appliances and similar applications	Data as supplied by the manufacturer		
	AC-7B	Motor load for household appliances			
	AC-8A	Switching of hermetically enclosed refrigerant compressor motors with manual reset of overload releases[5)]			
	AC-8B	Switching of hermetically enclosed refrigerant compressor motors with automatic reset of overload releases[5)]			
	AC-53a	Switching of squirrel-cage motor with semi-conductor contactors			

10

Standards, formulae, tables

Utilisation categories for contactors and motor starters

				Verification of switching capacity						
	Switch off			Switch on				Switch off		
cos φ	$\frac{I_c}{I_e}$	$\frac{U_r}{U_e}$	cos φ	$\frac{I_e}{A}$	$\frac{I}{I_e}$	$\frac{U}{U_e}$	cos φ	$\frac{I_c}{I_e}$	$\frac{U_r}{U_e}$	cos φ
0.95	1	1	0.95	All values	1.5	1.05	0.8	1.5	1.05	0.8
0.65	2.5	1	0.65	All values	4	1.05	0.65	4	1.05	0.8
0.65 0.35	1 1	0.17 0.17	0.65 0.35	$I_e \leqq 100$ $I_e > 100$	8 8	1.05 1.05	0.45 0.35	8 8	1.05 1.05	0.45 0.35
0.65 0.35	6 6	1 1	0.65 0.35	$I_e \leqq 100$ $I_e > 100$	10 10	1.05 1.05	0.45 0.35	10 10	1.05 1.05	0.45 0.35
					3.0	1.05	0.45	3.0	1.05	0.45
					1.5[2)]	1.05	[2)]	1.5[2)]	1.05	[2)]
					1.5	1.05	0.8	1.5	1.05	0.8
					8.0	1.05	[1)]	8.0	1.05	[1)]
					6.0	1.05	[1)]	6.0	1.05	[1)]
					6.0	1.05	[1)]	6.0	1.05	[1)]
					8.0	1.05	0.35	8.0	1.05	0.35

Standards, formulae, tables

Utilisation categories for contactors and motor starters

Type of current	Utilization category	Typical applications: I = Switch-on current, I_c = Switch-off current, I_e = Rated operational current, U = voltage, U_e = Rated operational voltage, U_r = Recovery voltage	Verification of electrical endurance		
			Switch on		
			$\frac{I_e}{A}$	$\frac{I}{I_e}$	$\frac{U}{U_e}$
Direct current	DC-1	Non-inductive or slightly inductive loads, resistance furnaces	All values	1	1
	DC-3	Shunt motors: starting, plugging, reversing, inching, dynamic braking	All values	2.5	1
	DC-5	Series motors: starting, plugging, reversing, inching, dynamic braking	All values	2.5	1
	DC-6	Switching of incandescent lamps			

To IEC/EN 947 4-1-60947, VDE 0660 Part 102

1) $\cos\varphi = 0{,}45$ for $I_e \leqq 100$ A; $\cos\varphi = 0{,}35$ for $I_e > 100$ A.

2) Tests must be carried out with an incandescent lamp load connected.

3) Here, the test data are to be derived from the AC-3 or AC-4 test values in accordance with TableVIIb, IEC/EN 60 947-4-1.

Standards, formulae, tables

Utilisation categories for contactors and motor starters

				Verification of switching capacity						
	Switch off			Switch on				Switch off		
L/R ms	$\frac{I_c}{I_e}$	$\frac{U_r}{U_e}$	L/R ms	$\frac{I_e}{A}$	$\frac{I}{I_e}$	$\frac{U}{U_e}$	L/R ms	$\frac{I_c}{I_e}$	$\frac{U_r}{U_e}$	L/R ms
1	1	1	1	All values	1.5	1.05	1	1.5	1.05	1
2	2.5	1	2	All values	4	1.05	2.5	4	1.05	2.5
7.5	2.5	1	7.5	All values	4	1.05	15	4	1.05	15
					1.5[2)]	1.05	[2)]	1.5[2)]	1.05	[2)]

4) Devices for utilization category AC-3 may be used for occasional inching or plugging during a limited period such as for setting up a machine; during this limited time period, the number of operations must not exceed a total of five per minute or more than ten in a ten minute period.

5) Hermetically enclosed refrigerant compressor motor means a combination of a compressor and a motor both of which are housed in the same enclosure with no external shaft or shaft seals, the motor running in the refrigerant.

Standards, formulae, tables

Utilisation categories for switch-disconnectors

Type of current	Utilization category	Typical applications: I = switch-on current, I_c = Switch-off current, I_e = Rated operational current, U = voltage, U_e = Rated operational voltage, U_r = Recovery voltage
Alternating current	AC-20 A(B)[1)]	Making and breaking without load
	AC-21 A(B)[1)]	Switching resistive loads including low overloads
	AC-22 A(B)[1)]	Switching mixed resistive and inductive loads including low overloads
	AC-23 A(B)[1)]	Switching motors and other highly inductive loads
Direct current	DC-20 A(B)[1)]	Making and breaking without load
	DC-21 A(B)[1)]	Switching resistive loads including low overloads
	DC-22 A(B)[1)]	Switching mixed resistive and inductive loads, including low overloads (e.g. shunt motors)
	DC-23 A(B)[1)]	Switching highly inductive loads (e.g. series motors)

1) A: Frequent operation, B: Occassional operation.

For load-break switches, switch-disconnectors and switch-fuse units to IEC/EN 60947-3 (VDE 0660 part 107).

Switch-disconnectors that are suitable for switching motors are also tested according to the criteria stated in → section "Utilisation categories for contactors and motor starters", page 10-34.

10

Standards, formulae, tables

Utilisation categories for switch-disconnectors

Verification of switching capacity						
Switch on				Switch off		
$\frac{I_e}{A}$	$\frac{I}{I_e}$	$\frac{U}{U_e}$	$\cos\varphi$	$\frac{I_c}{I_e}$	$\frac{U_r}{U_e}$	$\cos\varphi$
All values	1)		1)	1)		1)
All values	1.5	1.05	0.95	1.5	1.05	0.95
All values	3	1.05	0.65	3	1.05	0.65
$I_e \leqq 100$ $I_e > 100$	10 10	1.05 1.05	0.45 0.35	8 8	1.05 1.05	0.45 0.35
$\frac{I_e}{A}$	$\frac{I}{I_e}$	$\frac{U}{U_e}$	L/R ms	$\frac{I_c}{I_e}$	$\frac{U_r}{U_e}$	L/R ms
All values	1)	1)	1)	1)	1)	1)
All values	1.5	1.05	1	1.5	1.05	1
All values	4	1.05	2.5	4	1.05	2.5
All values	4	1.05	15	4	1.05	15

Standards, formulae, tables

Rated motor currents

Rated motor currents of three-phase motors (guideline values for cage motors)

Smallest possible short-circuit protection for three-phase motor

The maximum value is determined by the switchgear or overload relay.

The rated motor currents are for standard 1500 r.p.m. motors with normal inner and outer surface cooling.

D.O.L. starting:	Maximum starting current: 6 × rated current Maximum starting time: 5 sec.
Y/△ starting:	Maximum starting current: 2 × rated current Maximum starting time: 15 sec. Motor overload relay in phase current: set to 0.58 × rated current.

Rated fuse currents for Y/△ starting also apply to three-phase motors with slip-ring rotors.

For higher rated currents, starting currents and/or longer starting times, larger fuses will be required.

Table applies for time-lag and gL fuses (VDE 0636).

In the case of low-voltage h.b.c. fuses (NH type) with aM characteristics, fuses are to be selected according to their current rating.

Standards, formulae, tables

Rated motor currents

Motor rating			230 V			400 V		
			Rated motor current	Fuse		Rated motor current	Fuse	
				Direct starting	Y/△		Direct starting	Y/△
kW	cos φ	η [%]	A	A	A	A	A	A
0.06	0.7	58	0.37	2	–	0.21	2	–
0.09	0.7	60	0.54	2	–	0.31	2	–
0.12	0.7	60	0.72	4	2	0.41	2	–
0.18	0.7	62	1.04	4	2	0.6	2	–
0.25	0.7	62	1.4	4	2	0.8	4	2
0.37	0.72	66	2	6	4	1.1	4	2
0.55	0.75	69	2.7	10	4	1.5	4	2
0.75	0.79	74	3.2	10	4	1.9	6	4
1.1	0.81	74	4.6	10	6	2.6	6	4
1.5	0.81	74	6.3	16	10	3.6	6	4
2.2	0.81	78	8.7	20	10	5	10	6
3	0.82	80	11.5	25	16	6.6	16	10
4	0.82	83	14.8	32	16	8.5	20	10
5.5	0.82	86	19.6	32	25	11.3	25	16
7.5	0.82	87	26.4	50	32	15.2	32	16
11	0.84	87	38	80	40	21.7	40	25
15	0.84	88	51	100	63	29.3	63	32
18.5	0.84	88	63	125	80	36	63	40
22	0.84	92	71	125	80	41	80	50
30	0.85	92	96	200	100	55	100	63
37	0.86	92	117	200	125	68	125	80
45	0.86	93	141	250	160	81	160	100
55	0.86	93	173	250	200	99	200	125
75	0.86	94	233	315	250	134	200	160
90	0.86	94	279	400	315	161	250	200
110	0.86	94	342	500	400	196	315	200
132	0.87	95	401	630	500	231	400	250
160	0.87	95	486	630	630	279	400	315
200	0.87	95	607	800	630	349	500	400
250	0.87	95	–	–	–	437	630	500
315	0.87	96	–	–	–	544	800	630
400	0.88	96	–	–	–	683	1000	800
450	0.88	96	–	–	–	769	1000	800
500	0.88	97	–	–	–	–	–	–
560	0.88	97	–	–	–	–	–	–
630	0.88	97	–	–	–	–	–	–

Standards, formulae, tables
Rated motor currents

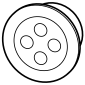
Motor rating			500 V			690 V		
			Rated motor current	Fuse Direct starting	Fuse Y/△	Rated motor current	Fuse Direct starting	Fuse Y/△
kW	cos φ	η [%]	A	A	A	A	A	A
0.06	0.7	58	0.17	2	–	0.12	2	–
0.09	0.7	60	0.25	2	–	0.18	2	–
0.12	0.7	60	0.33	2	–	0.24	2	–
0.18	0.7	62	0.48	2	–	0.35	2	–
0.25	0.7	62	0.7	2	–	0.5	2	–
0.37	0.72	66	0.9	2	2	0.7	2	–
0.55	0.75	69	1.2	4	2	0.9	4	2
0.75	0.79	74	1.5	4	2	1.1	4	2
1.1	0.81	74	2.1	6	4	1.5	4	2
1.5	0.81	74	2.9	6	4	2.1	6	4
2.2	0.81	78	4	10	4	2.9	10	4
3	0.82	80	5.3	16	6	3.8	10	4
4	0.82	83	6.8	16	10	4.9	16	6
5.5	0.82	86	9	20	16	6.5	16	10
7.5	0.82	87	12.1	25	16	8.8	20	10
11	0.84	87	17.4	32	20	12.6	25	16
15	0.84	88	23.4	50	25	17	32	20
18.5	0.84	88	28.9	50	32	20.9	32	25
22	0.84	92	33	63	32	23.8	50	25
30	0.85	92	44	80	50	32	63	32
37	0.86	92	54	100	63	39	80	50
45	0.86	93	65	125	80	47	80	63
55	0.86	93	79	160	80	58	100	63
75	0.86	94	107	200	125	78	160	100
90	0.86	94	129	200	160	93	160	100
110	0.86	94	157	250	160	114	200	125
132	0.87	95	184	250	200	134	250	160
160	0.87	95	224	315	250	162	250	200
200	0.87	95	279	400	315	202	315	250
250	0.87	95	349	500	400	253	400	315
315	0.87	96	436	630	500	316	500	400
400	0.88	96	547	800	630	396	630	400
450	0.88	96	615	800	630	446	630	630
500	0.88	97	–	–	–	491	630	630
560	0.88	97	–	–	–	550	800	630
630	0.88	97	–	–	–	618	800	630

Standards, formulae, tables
Conductors

Wiring and cable entries with grommets

Cable entry into closed devices is considerably simplified and improved by using cable grommets.

Cable grommets
For direct and quick cable entry into an enclosure and as a plug.

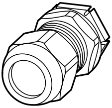
Membrane grommets metric	Cable entry	Hole diamter mm	Cable external diameter mm	For use with NYM/NYY cables, 4-core mm²	Cable grommet
	M16	16.5	1 – 9	H03VV-F3 × 0.75 NYM 1 × 16/3 × 1.5	KT-M16
	M20	20.5	1 – 13	H03VV-F3 × 0.75 NYM 5 × 1.5/5 × 2.5	KT-M20
• IP66, with integrated push-through diaphragm • PE and thermoplastic elastomer, halogen free	M25	25.5	1 – 18	H03VV-F3 × 0.75 NYM 4× 10	KT-M25
	M32	32.5	1 – 25	H03VV-F3 × 0.75 NYM 4 × 16/5 × 10	KT-M32

Detailed information on material properties
→ table, page 10-45.

Standards, formulae, tables
Conductors

Wiring and cable entries with cable glands

Metric cable glands to EN 50262
with 9, 10, 12, 14 or 15 mm long thread.

Cable glands	Cable entry	Hole diamter mm	Cable external diameter mm	For use with NYM/NYY cables, 4-core mm²	Cableglands Type
 • With lock nut and built-in strain relief • IP68 up to 5 bar, polyamide, halogen-free	M12	12.5	3 –7	H03VV-F3 × 0.75 NYM 1 × 2.5	V-M12
	M16	16.5	4.5 – 10	H05VV-F3 × 1.5 NYM 1 × 16/3 × 1.5	V-M16
	M20	20.5	6 – 13	H05VV-F4 × 2.5/3 × 4 NYM 5 × 1.5/5 × 2.5	V-M20
	M25	25.5	9 – 17	H05VV-F5 × 2.5/5 × 4 NYM 5 × 2.5/5 × 6	V-M25
	M32	32.5	13 – 21	NYM 5 × 10	V-M32
	M32	32.5	18 – 25	NYM 5 × 16	V-M32G1)
	M40	40.5	16 – 28	NYM 5 × 16	V-M40
	M50	50.5	21 – 35	NYM 4 × 35/5 × 25	V-M50
	M63	63.5	34 – 48	NYM 4 × 35	V-M63

1) Does not correspond to EN 50262.

Detailed information on material properties
→ table, page 10-45.

Standards, formulae, tables

Conductors

Material characteristics

	KT-M…	V-M…
Material	Polyethylene and thermoplastic elastomer	Polyamide, halogen free
Colour	Grey, RAL 7035	Grey, RAL 7035
Protection type	up to IP66	IP68 up to 5 bar (30 min)
Chemical resistant	Resistant to: • Alcohol, • Animal and plant-based oils, • Weak alkalis, • Weak acids, • water	Resistant to: • Acetone, • Petrol, • paraffin, • Diesel oil, • Greases, • Oils, • Solvents for paints and lacquers
Danger of stress fracture	Relative high	low
Heat resistance	–40 °C…80 °C, short-time up to approx. 100 °C	–20 °C…100 °C, short-time up to approx. 120 °C
Flame retardant	–	Glow wire test 750 °C according to EN 60695-2-11
Flammability to UL94	–	V2

Standards, formulae, tables
Conductors

External diameter of conductors and cables

Number of conductors	Approximate external diameter (average of various makes) NYM	NYY	H05 RR-F	H07 RN-F	NYCY NYCWY
Cross-section mm²	mm max.	mm	mm max.	mm max.	mm
2 × 1.5	10	11	9	10	12
2 × 2.5	11	13	13	11	14
3 × 1.5	10	12	10	10	13
3 × 2.5	11	13	11	12	14
3 × 4	13	17	–	14	15
3 × 6	15	18	–	16	16
3 × 10	18	20	–	23	18
3 × 16	20	22	–	25	22
4 × 1.5	11	13	9	11	13
4 × 2.5	12	14	11	13	15
4 × 4	14	16	–	15	16
4 × 6	16	17	–	17	18
4 × 10	18	19	–	23	21
4 × 16	22	23	–	27	24
4 × 25	27	27	–	32	30
4 × 35	30	28	–	36	31
4 × 50	–	30	–	42	34
4 × 70	–	34	–	47	38
4 × 95	–	39	–	53	43
4 × 120	–	42	–	–	46
4 × 150	–	47	–	–	52
4 × 185	–	55	–	–	60
4 × 240	–	62	–	–	70
5 × 1.5	11	14	12	14	15
5 × 2.5	13	15	14	17	17
5 × 4	15	17	–	19	18
5 × 6	17	19	–	21	20
5 × 10	20	21	–	26	–
5 × 16	25	23	–	30	–
8 × 1.5	–	15	–	–	–
10 × 1.5	–	18	–	–	–
16 × 1.5	–	20	–	–	–
24 × 1.5	–	25	–	–	–

NYM: sheathed conductor
NYY: plastic-sheathed cable
H05RR-F: light rubber-sheathed flexible cable (NLH + NSH)
NYCY: cable with concentric conductor and plastic sheath
NYCWY: cable with concentric wave-form conductor and plastic sheath

Standards, formulae, tables

Conductors

Cables and wiring, type abbreviation

Identification of specification

Harmonized specification	H
Recognized national type	A

Rated operational voltage U_0/U

300/300V	03
300/500V	05
450/750V	07

Insulating material

PVC	V
Natural and/or synthetic rubber	R
Silicon rubber	S

Sheathing material

PVC	V
Natural and/or synthetic rubber	R
Polychloroprene rubber	N
Fibre-glass braid	J
Textile braid	T

Special construction feature

Flat, separable conductor	H
Flat, non-separable conductor	H2

Type of conductor

Solid	-U
Stranded	-R
Flexible with cables for fixed installation	-K
Flexible with flexible cables	-F
Highly flexible with flexible cables	-H
Tinsel cord	-Y

Number of cores ...

Protective conductor

Without protective conductors	X
With protective conductors	G

Rated conductor cross-section ...

Examples for complete cable designation

PVC-sheathed wire, 0.75 mm² flexible, H05V-K 0.75 black

Heavy rubber-sheathed cable, 3-core, 2.5 mm² without green/yellow protective conductor A07RN-F3 × 2.5

Standards, formulae, tables
Conductors

Rated operational currents and short-circuit currents for standard transformers

Rated voltage				
U_n	400/230 V			525 V
Short-circuit voltage U_K		4 %	6 %	
Rating	Rated current I_n	Short-circuit current I''_K		Rated current I_n
kVA	A	A	A	A
50	72	1967	–	55
63	91	2478	1652	69
100	144	3933	2622	110
125	180	4916	3278	137
160	231	6293	4195	176
200	289	7866	5244	220
250	361	9833	6555	275
315	455	12390	8260	346
400	577	15733	10489	440
500	722	19666	13111	550
630	909	24779	16519	693
800	1155	–	20977	880
1000	1443	–	26221	1100
1250	1804	–	32777	1375
1600	2309	–	41954	1760
2000	2887	–	52443	2199
2500	3608	–	65553	2749

Standards, formulae, tables
Conductors

		690/400 V		
4 %	6 %		4 %	6 %
Short-circuit current		Rated current	Short-circuit current	
I_K''		I_n	I_K''	
A	A	A	A	A
1498	–	42	1140	–
1888	1259	53	1436	958
2997	1998	84	2280	1520
3746	2497	105	2850	1900
4795	3197	134	3648	2432
5993	3996	167	4560	3040
7492	4995	209	5700	3800
9440	6293	264	7182	4788
11987	7991	335	9120	6080
14984	9989	418	11401	7600
18879	12586	527	14365	9576
–	15983	669	–	12161
–	19978	837	–	15201
–	24973	1046	–	19001
–	31965	1339	–	24321
–	39956	1673	–	30402
–	49945	2092	–	38002

Standards, formulae, tables

Formulea

Ohm's Law

$U = I \times R \ [V]$	$I = \frac{U}{R} \ [A]$	$R = \frac{U}{I} \ [\Omega]$

Resistance of a piece of wire

$R = \frac{l}{\chi \times A} \ [\Omega]$	Copper:	$\chi = 57 \frac{m}{\Omega mm^2}$
l = Length of conductor [m]	Aluminium:	$\chi = 33 \frac{m}{\Omega mm^2}$
χ = Conductivity [m/Ωmm²]	Iron:	$\chi = 8{,}3 \frac{m}{\Omega mm^2}$
A = Conductor cross section [mm²]	Zinc:	$\chi = 15{,}5 \frac{m}{\Omega mm^2}$

Resistors

Transformer	$X_L = 2 \times \pi \times f \times L \ [\Omega]$	
Capacitors	$X_C = \frac{1}{2 \times \pi \times f \times C} \ [\Omega]$	
Impedance	$Z = \sqrt{R^2 + (X_L - X_C)^2}$	$Z = \frac{R}{\cos\varphi} \ [\Omega]$

L = Inductance [H]

C = Capacitance [F]

X_L = Inductive impedance [Ω]

X_C = Capacitive impedance [Ω]

f = Frequency [Hz]

φ = Phase angle

Parallel connection of resistances

With 2 parallel resistances:	With 3 parallel resistances:
$R_g = \frac{R_1 \times R_2}{R_1 + R_2} \ [\Omega]$	$R_g = \frac{R_1 \times R_2 \times R_3}{R_1 \times R_2 + R_2 \times R_3 + R_1 \times R_3} \ [\Omega]$

General calculation of resistances:

$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots [1/\Omega]$	$\frac{1}{Z} = \frac{1}{Z_1} + \frac{1}{Z_2} + \frac{1}{Z_3} + \ldots [1/\Omega]$
$\frac{1}{X} = \frac{1}{X_1} + \frac{1}{X_2} + \frac{1}{X_3} + \ldots [1/\Omega]$	

Standards, formulae, tables
Formulea

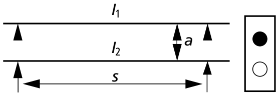
Electric power

	Power	Current consumption
Direct current	$P = U \times I\ [W]$	$I = \frac{P}{U}[A]$
Single-phase AC	$P = U \times I \times \cos\varphi [W]$	$I = \frac{P}{U \times \cos\varphi}[A]$
Alternating current	$P = \sqrt{3} \times U \times I \times \cos\varphi [W]$	$I = \frac{P}{\sqrt{3} \times U \times \cos\varphi}[A]$

Mechanical force between 2 parallel conductors

2 conductors with currents I_1 and I_2

$$F_2 = \frac{0{,}2 \times I_1 \times I_2 \times s}{a}[N]$$



s = Support spacing clearance [cm]

a = Support spacing clearance [cm]

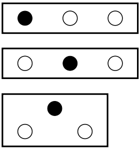
Mechanical force between 3 parallel conductors

3 conductors with current I

$F_3 = 0{,}808 \times F_2 [N]$

$F_3 = 0{,}865 \times F_2 [N]$

$F_3 = 0{,}865 \times F_2 [N]$



Standards, formulae, tables
Formulea

Voltage drop

	Known power	Known current
Direct current	$\Delta U = \frac{2 \times l \times P}{\chi \times A \times U}$ [V]	$\Delta U = \frac{2 \times l \times I}{\chi \times A}$ [V]
Single-phase AC	$\Delta U = \frac{2 \times l \times P}{\chi \times A \times U}$ [V]	$\Delta U = \frac{2 \times l \times I}{\chi \times A} \times \cos\varphi$ [V]
Alternating current	$\Delta U = \frac{l \times P}{\chi \times A \times U}$ [V]	$\Delta U = \sqrt{3} \times \frac{l \times I}{\chi \times A} \times \cos\varphi$ [V]

Calculation of cross-section from voltage drop

Direct current	Single-phase AC	Alternating current
Known power		
$A = \frac{2 \times l \times P}{\chi \times \Delta u \times U}$ [mm²]	$A = \frac{2 \times l \times P}{\chi \times \Delta u \times U}$ [mm²]	$A = \frac{l \times P}{\chi \times \Delta u \times U}$ [mm²]
Known current		
$A = \frac{2 \times l \times I}{\chi \times \Delta u}$ [mm²]	$A = \frac{2 \times l \times I}{\chi \times \Delta u} \times \cos\varphi$ [mm²]	$A = \sqrt{3} \times \frac{l \times I}{\chi \times \Delta u} \times \cos\varphi$ [mm²

10

Power loss

Direct current	Single-phase AC
$P_{Verl} = \frac{2 \times l \times P \times P}{\chi \times A \times U \times U}$ [W]	$P_{Verl} = \frac{2 \times l \times P \times P}{\chi \times A \times U \times U \times \cos\varphi \times \cos\varphi}$ [W]
Alternating current	
$P_{Verl} = \frac{l \times P \times P}{\chi \times A \times U \times U \times \cos\varphi \times \cos\varphi}$ [W]	

l = Single length of conductor [m];
A = Conductor cross section [mm²];
χ = Conductivity (copper: $\chi = 57$; aluminium: $\chi = 33$; iron: $\chi = 8.3 \frac{m}{\Omega mm^2}$)
Δu = Voltage drop

Standards, formulae, tables
Formulea

Power of electric motors

	Output	Current consumption
Direct current	$P_1 = U \times I \times \eta$ [W]	$I = \frac{P_1}{U \times \eta}$ [A]
Single-phase AC	$P_1 = U \times I \times \cos\varphi \times \eta$ [W]	$I = \frac{P_1}{U \times \cos\varphi \times \eta}$ [A]
Alternating current	$P_1 = (1{,}73) \times U \times I \times \cos\varphi \times \eta$ [W]	$I = \frac{P_1}{(1{,}73) \times U \times \cos\varphi \times \eta}$ [A]

P_1 = Rated mechanical power at the motor shaft
P_2 = Electrical power consumption

Efficiency	$\eta = \frac{P_1}{P_2} \times (100\ \%)$	$P_2 = \frac{P_1}{\eta}$ [W]

Number of poles	Synchronous speed	Full-load speed
2	3000	2800 – 2950
4	1500	1400 – 1470
6	1000	900 – 985
8	750	690 – 735
10	600	550 – 585

Synchronous speed = approx. no-load speed

Standards, formulae, tables

Standard international units

International Unit System (SI)

Basic parameters Physical parameters	Symbol	SI basic unit	Further related SI units
Length	l	m (Metre)	km, dm, cm, mm, µm, nm, pm
Mass	m	kg (Kilogram)	Mg, g, mg, µg
Time	t	s (Second)	ks, ms, µs, ns
Electrical current	I	A (Ampere)	kA, mA, µA, nA, pA
Thermo-dynamic temperature	T	K (Kelvin)	–
Amount of substance	n	mole (Mol)	Gmol, Mmol, kmol, mmol, µmol
Light intensity	I_v	cd (Candela)	Mcd, kcd, mcd

Factors for conversion of old units into SI units

Conversion factors

Size	Old unit	SI unit exact	Approximate
Force	1 kp 1 dyn	9.80665 N $1 \cdot 10^{-5}$ N	10 N $1 \cdot 10^{-5}$ N
Momentum of force	1 mkp	9.80665 Nm	10 Nm
Pressure	1 at 1 Atm = 760 Torr 1 Torr 1 mWS 1 mmWS 1 mmWS	0.980665 bar 1.01325 bar 1.3332 mbar 0.0980665 bar 0.0980665 mbar 9.80665 Pa	1 bar 1.01 bar 1.33 bar 0.1 bar 0.1 mbar 10 Pa
Tension	$1 \frac{kp}{mm^2}$	$9,80665 \frac{N}{mm^2}$	$10 \frac{N}{mm^2}$
Energy	1 mkp 1 kcal 1 erg	9.80665 J 4.1868 kJ $1 \cdot 10^{-7}$ J	10 J 4.2 kJ $1 \cdot 10^{-7}$ J

Standards, formulae, tables

Standard international units

Conversion factors

Size	Old unit	SI unit exact	Approximate
Power	$1\frac{kcal}{h}$	$4{,}1868\frac{kJ}{h}$	$4{,}2\frac{kJ}{h}$
	$1\frac{kcal}{h}$	1.163 W	1.16 W
	1 PS	0.73549 kW	0.74 kW
Heat transfer coefficient	$1\frac{kcal}{m^2h°C}$	$4{,}1868\frac{kJ}{m^2hK}$	$4{,}2\frac{kJ}{m^2hK}$
	$1\frac{kcal}{m^2h°C}$	$1{,}163\frac{W}{m^2K}$	$1{,}16\frac{W}{m^2K}$
dynamic viscosity	$1 \cdot 10^{-6}\ \frac{kps}{m^2}$	$0,\ 980665 \cdot 10^{-5}\ \frac{Ns}{m^2}$	$1 \cdot 10^{-5}\frac{Ns}{m^2}$
	1 Poise	$0{,}1\ \frac{Ns}{m^2}$	$0{,}1\ \frac{Ns}{m^2}$
	1 Poise 0.1	$Pa \cdot s$	
Kinetic viscosity	1 Stokes	$1 \cdot 10^{-4}\ \frac{m^2}{s}$	$1 \cdot 10^{-4}\ \frac{m^2}{s}$
Angle (flat)	1	$\frac{1}{360}$pla	$2,\ 78 \cdot 10^{-3}$pla
	1 gon	$\frac{1}{400}$pla	$2,\ 5 \cdot 10^{-3}$pla
	1	$\frac{\pi}{180}$rad	$17,\ 5 \cdot 10^{-3}$rad
	1 gon	$\frac{\pi}{200}$rad	$15,\ 7 \cdot 10^{-3}$pla
	57,296		1 rad
	63,662 gon		1 rad

10

Standards, formulae, tables
Standard international units

Conversion of SI units, coherences

Conversion of SI units and coherences				
Size	SI units name	Symbol	Basic unit	Conversion of SI units
Force	Newton	N	$1 \cdot \frac{kg \cdot m}{s^2}$	
Force momentum	Newton-metre	Nm	$1 \cdot \frac{kg \cdot m^2}{s^2}$	
Pressure	Bar	bar	$10^5 \frac{kg}{m \cdot s^2}$	$1\ bar = 10^5 Pa = 10^5 \frac{N}{m^2}$
	Pascal	Pa	$1 \cdot \frac{kg}{m \cdot s^2}$	$1\ Pa = 10^{-5} bar$
Energy, heat	Joule	J	$1 \cdot \frac{kg \cdot m^2}{s^2}$	1 J = 1 Ws = 1 Nm
Power	Watt	W	$1 \cdot \frac{kg \cdot m^2}{s^3}$	$W = 1\frac{J}{s} = 1\frac{N \cdot m}{s}$
Tension		$\frac{N}{mm^2}$	$10^6 \frac{kg}{m \cdot s^2}$	$1\frac{N}{mm^2} = 10^2 \frac{N}{cm^2}$
Angle (flat)	Degree Gon	1 gon		360° = 1 pla = 2π rad 400 gon = 360°
	Radian	rad	$1\frac{m}{m}$	
	Full circle	pla		1 pla = 2π rad = 360°
Voltage	Volt	V	$1 \cdot \frac{kg \cdot m^2}{s^3 \cdot A}$	$1\ V = 1 \cdot \frac{W}{A}$
Resistor	Ohm	Ω	$1 \cdot \frac{kg \cdot m^2}{s^3 \cdot A^2}$	$1\ \Omega = 1 \cdot \frac{V}{A} = 1 \cdot \frac{W}{A^2}$
Conductivity	Siemens	S	$1 \cdot \frac{s^3 \cdot A^2}{kg \cdot m^2}$	$1\ S = 1 \cdot \frac{A}{V} = 1 \cdot \frac{A^2}{W}$
Electric charge	Coulomb	C	1 · A · s	

10

Standards, formulae, tables

Standard international units

Conversion of SI units and coherences

Size	SI units name	Symbol	Basic unit	Conversion of SI units
Capacity	Farad	F	$1 \cdot \frac{s^4 \cdot A}{kg \cdot m^2}$	$1\ F = 1 \cdot \frac{C}{V} = 1 \cdot \frac{s \cdot A^2}{W}$
Field strength		$\frac{V}{m}$	$1 \cdot \frac{kg \cdot m}{s^3 \cdot A}$	$1 \frac{V}{m} = 1 \cdot \frac{W}{A \cdot m}$
Flux	Weber	W_b	$1 \cdot \frac{kg \cdot m^2}{s^2 \cdot A}$	$1\ W_b = 1 \cdot V \cdot s = 1 \cdot \frac{W \cdot s}{A}$
Flux density	Tesla	T	$1 \cdot \frac{kg}{s^2 \cdot A}$	$1\ T = \frac{W_b}{m^2} = 1 \cdot \frac{V \cdot s}{m^2} = 1 \cdot \frac{W \cdot s}{m^2 A}$
Inductance	Henry	H	$1 \cdot \frac{kg \cdot m^2}{s^2 \cdot A^2}$	$1\ H = \frac{W_b}{A} = 1 \cdot \frac{V \cdot s}{A} = 1 \cdot \frac{W \cdot s}{A^2}$

Decimal powers (parts and multiples of units)

Power	Prefix	Symbol	Power	Prefix	Symbol
10^{-18}	Atto	a	10^{-1}	Deci	d
10^{-15}	Femto	f	10	Deca	da
10^{-12}	Pico	p	10^{2}	Hecto	h
10^{-9}	Nano	n	10^{3}	Kilo	k
10^{-6}	Micro	µ	10^{6}	Mega	M
10^{-3}	Milli	m	10^{9}	Giga	G
10^{-2}	Centi	c	10^{12}	Tera	T

Standards, formulae, tables

Standard international units

Physical units

Obsolete units

Mechanical force

SI unit:		N (Newton) J/m (Joule/m)		
Previous unit:		kp (kilopond) dyn (Dyn)		
1 N	= 1 J/m	= 1 kg m/s^2	= 0.102 kp	= 10^5 dyn
1 J/m	= 1 N	= 1 kg m/s^2	= 0.102 kp	= 10^5 dyn
1 kg m/s^2	= 1 N	= 1 J/m	= 0.102 kp	= 10^5 dyn
1 kp	= 9.81 N	= 9.81 J/m	= 9.81 kg m/s^2	= 0.981 10^6 dyn
1 dyn	= 10^{-5} N	= 10^{-5} J/m	= 10^{-5} kg m/s^2	= 1,02 10^{-5} kp

Pressure

SI unit:		Pa (Pascal) bar (Bar)		
Previous unit:		at = kp/cm^2 = 10 m Ws Torr = mm Hg atm		
1 Pa	= 1 N/m^2	= 10^{-5} bar		
1 Pa	= 10^{-5} bar	= 10,2 · 10^{-6} at	= 9,87 · 10^{-6} at	= 7,5 · 10^{-3} Torr
1 bar	= 10^5 Pa	= 1.02 at	= 0.987 at	= 750 Torr
1 at	= 98.1 · 10^3 Pa	= 0.981 bar	= 0.968 at	= 736 Torr
1 atm	= 101.3 · 10^3 Pa	= 1.013 bar	= 1.033 at	= 760 Torr
1 Torr	= 133.3 Pa	= 1.333 · 10^{-3} bar	= 1.359 · 10^{-3} at	= 1.316 · 10^{-3} atm

Standards, formulae, tables
Standard international units

Work

SI unit:	J (Joule) Nm (Newtonmeter)
SI unit: (as before)	Ws (Wattsecond) kWh (Kilowatthour)
Previous unit:	kcal (Kilocalorie) = cal · 10^{-3}

1 Ws	= 1 J	= 1 Nm	10^7 erg		
1 Ws	= 278 · 10^{-9} kWh	= 1 Nm	= 1 J	= 0.102 kpm	= 0.239 cal
1 kWh	= 3.6 · 10^6 Ws	= 3.6 · 10^6 Nm	= 3.6 · 10^6 J	= 367 · 10^6 kpm	= 860 kcal
1 Nm	= 1 Ws	= 278 · 10^{-9} kWh	= 1 J	= 0.102 kpm	= 0.239 cal
1 J	= 1 Ws	= 278 · 10^{-9} kWh	= 1 Nm	= 0.102 kpm	= 0.239 cal
1 kpm	= 9.81 Ws	= 272 · 10^{-6} kWh	= 9.81 Nm	= 9.81 J	= 2.34 cal
1 kcal	= 4.19 · 10^3 Ws	= 1.16 · 10^{-3} kWh	= 4.19 · 10^3 Nm	= 4.19 · 10^3 J	= 427 kpm

Power

SI unit:	Nm/s (Newtonmetre/s) J/s (Joule/s)
SI unit: (as before)	W (Watt) kW (Kilowatt)
Previous unit:	kcal/s (Kilocalorie/sec.) = cal/s · 10^3 kcal/h (Kilocalorie/hour.) = cal/h · 10^6 kpm/s (Kilopondmetre/Sec.) PS (metric horsepower)

1 W	= 1 J/s	= 1 Nm/s			
1 W	= 10^{-3} kW	= 0.102 kpm/s	= 1.36 · 10^{-3} PS	= 860 cal/h	= 0.239 cal/s
1 kW	= 10^3 W	= 102 kpm/s	= 1.36 PS	= 860 · 10^3 cal/h	= 239 cal/s
1 kpm/s	= 9.81 W	= 9.81 · 10^{-3} kW	= 13.3 · 10^{-3} PS	= 8.43 · 10^3 cal/h	= 2.34 cal/s
1 PS	= 736 W	= 0.736 kW	= 75 kpm/s	= 632 · 10^3 cal/h	= 176 cal/s
1 kcal/h	= 1.16 W	= 1.16 · 10^{-3} kW	= 119 · 10^{-3} kpm/s	= 1.58 · 10^{-3} PS	= 277.8 · 10^{-3} cal/s
1 cal/s	= 4.19 W	= 4.19 · 10^{-3} kW	= 0.427 kpm/s	= 5.69 · 10^{-3} PS	= 3.6 kcal/h

10

Standards, formulae, tables
Standard international units

Magnetic field strength

SI unit:		$\frac{A}{m}$ $\frac{\text{Ampere}}{\text{Meter}}$
Previous unit:		Oe = (Oerstedt)
$1\ \frac{A}{m}$	$= 0,001\ \frac{kA}{m}$	= 0.01256 Oe
$1\ \frac{kA}{m}$	$= 1000\ \frac{A}{m}$	= 12.56 Oe
1 Oe	$= 79,6\ \frac{A}{m}$	$= 0,0796\ \frac{kA}{m}$

Magnetic field strength

SI unit		Wb (Weber) µWb (Microweber)
Previous unit:		M = Maxwell
1 Wb	$= 1\ Tm^2$	
1 Wb	$= 10^6$ µWb	$= 10^8$ M
1 µWb	$= 10^{-6}$ Wb	= 100 M
1 M	$= 10^{-8}$ Wb	= 0.01 µWb

Magnetic flux density

SI unit:		T (Tesla) mT (Millitesla)
Previous unit:		G = Gauss
1 T	$= 1\ Wb/m^2$	
1 T	$= 10^3$ mT	$= 10^4$ G
1 mT	$= 10^{-3}$ T	= 10 G
1 G	$= 0,1^{-3}$ T	= 0,1 mT

Standards, formulae, tables

Standard international units

Conversion of Imperial/American units into SI units

Length	1 in	1 ft	1 yd	1 mile Land mile	1 mile Sea mile	
m	$25.4 \cdot 10^{-3}$	0.3048	0.9144	$1.609 \cdot 10^{3}$	$1.852 \cdot 10^{3}$	
Weight	1 lb	1 ton (UK) long ton	1 cwt (UK) long cwt	1 ton (US) short ton	1 ounce	1 grain
kg	0.4536	1016	50.80	907.2	$28.35 \cdot 10^{-3}$	$64.80 \cdot 10^{-6}$
Area	1 sq.in	1 sq.ft	1 sq.yd	1 acre	1 sq.mile	
m^2	$0.6452 \cdot 10^{-3}$	$92.90 \cdot 10^{-3}$	0.8361	$4.047 \cdot 10^{3}$	$2.590 \cdot 10^{3}$	
Volume	1 cu.in	1 cu.ft	1 cu.yd	1 gal (US)	1 gal (UK)	
m^3	$16.39 \cdot 10^{-6}$	$28.32 \cdot 10^{-3}$	0.7646	$3.785 \cdot 10^{-3}$	$4.546 \cdot 10^{-3}$	
Force	1 lb	1 ton (UK) long ton	1 ton (US) short ton	1 pdl (poundal)		
N	4.448	$9.964 \cdot 10^{3}$	$8.897 \cdot 10^{3}$	0.1383		
Speed	$1 \frac{mile}{h}$	1 knot	$1 \frac{ft}{s}$	$1 \frac{ft}{min}$		
$\frac{m}{s}$	0.447	0.5144	0.3048	$5.080 \cdot 10^{-3}$		
Pressure	$1 \frac{lb}{sq.in}$ 1 psi	1 in Hg	1 ft H_2O	1 in H_2O		
bar	$65.95 \cdot 10^{-3}$	$33.86 \cdot 10^{-3}$	$29.89 \cdot 10^{-3}$	$2.491 \cdot 10^{-3}$		
Energy, Work	1 HPh	1 BTU	1 PCU			
J	$2.684 \cdot 10^{6}$	$1.055 \cdot 10^{3}$	$1.90 \cdot 10^{3}$			

Standards, formulae, tables

Standard international units

Conversion of Imperial/American units into SI units

Length	1 cm	1 m	1 m	1 km	1 km
	0.3937 in	3.2808 ft	1.0936 yd	0.6214 mile (land mile)	0.5399 mile (sea mile)
Weight	1 g	1 kg	1 kg	1 t	1 t
	15.43 grain	35.27 ounce	2.2046 lb.	0.9842 long ton	1.1023 short ton
Area	$1 cm^2$	$1 m^2$	$1 m^2$	$1 m^2$	$1 km^2$
	0.155 sq.in	10.7639 sq.ft	1.196 sq.yd	$0.2471 \cdot 10^{-3}$ acre	0.3861 sq.mile
Volume	$1 cm^3$	1 l	$1 m^3$	$1 m^3$	$1 m^3$
	0.06102 cu.in	0.03531 cu.ft	1.308 cu.yd	264.2 gal (US)	219.97 gal (UK)
Force	1 N	1 N		1 N	1 N
	0.2248 lb	$0.1003 \cdot 10^{-3}$ long ton (UK)		$0.1123 \cdot 10^{-3}$ short ton (US)	7.2306 pdl (poundal)
Speed	1 m/s	1 m/s	1 m/s	1 m/s	
	3.2808 ft/s	196.08 ft/min	1.944 knots	2.237 mph	
Pressure	1 bar	1 bar	1 bar	1 bar	
	14.50 psi	29.53 in Hg	33.45 ft H_2O	401.44 in H_2O	
Energy, Work	1 J		1 J	1 J	
	$0.3725 \cdot 10^{-6}$ HPh		$0.9478 \cdot 10^{-3}$ BTU	$0.5263 \cdot 10^{-3}$ PCU	