General Technical Terms on Linear, Rotary and Holding Solenoids

1. Definitions according to VDE 0580*

1.1 Electrical definitions

The **rated voltage** U_N is that used by the manufacturer of the device in designating or identifying the supply voltage assigned for voltage devices.

The **signal voltage** U_B refers to the rated current and 20 °C winding temperature. Where appropriate, it also refers to the planned rated frequency in the specified operating mode.

The **power rating** P_N is a suitable rounded value of the power for designating and identifying the device.

The **design capability,** in the case of voltage devices, is the product of the rated voltage and the signal current. In case of current devices it is the product of the rated current and the signal voltage.

The **rated current** I_N is that used by the manufacturer of the device in designating or identifying the supply current assigned for current devices.

The **signal current** I_B refers to the rated voltage and 20 °C winding temperature. Where appropriate, it also refers to the rated frequency in the specified operating mode.

1.2 Time definitions

Switch on period is the time span between switch on and switch off of the excitation current.

Switch off period is the time span between switch off and switch on of the excitation current.

Operational cycle time is the sum of switch on period and current free pause.

Duty cycle (ED) is the ratio of switch on period to operational cycle time. Switch on reaction time.

Reaction delay is the time span between switch on of the excitation current and armature motion.

Stroke time[1] is the time span between commencement of armature motion and its end position.
Pull-in time is the sum of switch on reaction time and stroke time.[1]
Switch off reaction time is the span between switch off of the excitation current and the beginning of armature return motion.
Drop-out action time is the time span between commencement of return motion and attainment of armature start position.
Drop-out time is the sum of switch off reaction time and return action time.

1.3 Temperature definitions

The **reference temperature** ϑ_{11} is the temperature of an electromagnetic device when cold and when used in accordance with the regulations.

The **warm operating** condition is the condition at which the steady temperature is reached. The temperature of the warm operating condition is the overtemperature determined in section 5.5 minus the reference temperature. When not otherwise specified, the reference temperature is an ambient temperature of 35 °C.

2. Rated operational requirements

Electromagnetic devices must be constructed in such a way that their function and safety according to the regulations is guaranteed under the following conditions.

- Voltage range: + 6 %, - 10 % of the rated voltage in accordance with DIN IEC 38.
  Other voltage ranges of the rated voltage must be agreed upon by the manufacturer and user.
- frequency range: ± 1 % of the rated frequency,
- assembly height up to 1000 m in excess of N. N.,

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[1] In rotary solenoids, the rotational angle corresponds to the stroke.

- ambient temperature between -5 °C and +40 °C with a daily average of maximum +35 °C,
- relative humidity up to 50 % at +40 °C; higher humidity values at lower temperatures, e.g. 90 % at +20 °C.
  In case of non-serviceable devices, the manufacturer of the serviceable devices must take into account the influences of dew and icing.
- ambient air is not substantially polluted by dust, smoke, aggressive gases and steams or salt content.

Operational conditions that deviate from these or are aggravated must fulfil additional requirements that are to be agreed upon by the user and the manufacturer.

3. Standard data

The information given in tables for the following conditions:

Torque or Solenoid Force is given at 90 % of the rated voltage and with a warm winding. With a cold winding and the rated voltage, the value is significantly higher, according to solenoid type, current etc., approximately 15 to 50 %.

The standard DIN-IEC 0580 assumes a maximum acceptable operational cycle time of 5 minutes. This is valid for solenoids with an overall weight of approx. 50 g or more. For smaller solenoids a shorter operational cycle time has to be set, taking the respective cooling conditions into account.

4. Insulation classification

All linear and rotary solenoids with coil voltage ≦ 42 V comply with insulation specification III.
Models with plug-in sockets 6.3 according to DIN 46247 and electric screw terminal box with PG screw joint comply with insulation specification I with ground connector.
With models with coil voltage > 42 V, it is the client's responsibility to ensure that the appliance is fitted according to the insulation classification.

5. Variation in reference temperature

Solenoids may be operated at various reference temperatures provided that the permissible duty cycle is corrected by multiplying with the conversion factor given below. The torque or solenoid force, given with a warm winding is not influenced in this context.
Conversion factors for various reference temperatures.

20	35	50	75	Reference temperature (°C)
1,2	1	0,8	0,47	Conversion factor for duty cycle

Example: A solenoid with a rated duty cycle of 40 % can also be required to operate at a reference temperature of 50 °C. In this case the duty cycle is modified to 0.8 x 40 % = 32 % maximum, which must not be exceeded.

6. Insulation material classification

Insulating materials used with solenoids are classified according to their stability during constant heating. The limiting value of the overheating temperature is given by the maximum permissible temperature minus the reference temperature of 35 °C and minus empirically determined 5 °C for the heating point difference. All three listed materials are used in our solenoid ranges.

E	B	F	Insulation material class
120	130	155	Maximum permissible temperature (°C)
80	90	115	Maximum overheating temperature difference (K)

7. Insulation group

The insulation group for solenoids can be found in the technical data of the corresponding solenoid version. VDE 0580 and e.g. EN 60204, part 1, DIN VDE 0113 (for electrical equipment of industrial machines) supply you with information on the insulation group required for each different application.

7.1 Insulation group according to VDE 0580, Regulation for electromagnetic devices

Air gaps and creeping distance must comply with VDE 0110 “Regulations for the measuring of air gaps and creeping distances of electric production facilities”. The insulation group must correspond to the application conditions.

8. The law concerning industrial equipment

Any expert realizes straight away that solenoids of conventional design as such are not completely shockproof. At least the connections (plug and socket connectors) are not protected against accidental contact. Nor is this required in VDE 0435 as the necessary safety precautions can be met at much lower cost on relay installation.

In some applications, however, it must be expected that covers, doors etc. will be opened by laymen, to change a solenoid for example. Unless specified to the contrary in the regulations concerned we recommend applying VDE 0860 in such cases “Regulations for Power Operated Radio and Allied Equipment”, § 5b and 9i. This specifies that parts of the housing, covers etc. may only be opened with the aid of a tool if shock hazard components will be exposed thereby. If necessary a notice should be attached: “withdraw plug from power supply socket before removing cover” or something similar.

9. Plant safety

In plants where man's health or important values depend on the excellent operating of machines, measures have to be taken that avoid dangerous situations in the case of malfunctions.

Detailed requirements can be found in

- Electrical equipment of industrial machines – (para. 5.7) in DIN VDE 832
- Traffic signalling installation – (para. 4 and 15) or in TRA 200
- Technical regulation for lifts – (para. 261, 262)

If comparable requirements concerning safety are demanded and there are no technical rules for this application case, the above regulations can serve as guidelines.

10. Manufacturer's certificate (installer's certificate) according to VBG 4 § 5, para. 4

The VBG regulations are regulations for accident prevention and safety measures of those trade unions whose members are involved in the running of technical installations. The prevention of accident regulations VBG 4 apply to electrical installations and equipment. VBG 4 § 5 stipulates that the manager of an electrical installation or equipment has to test this equipment or have it tested by an approved electrical engineer before its first commercial operation. However, although § 5, para 4 VBG 4 often demands an all-embracing certificate (manufactuer's certificate) or equipment or parts which cannot operate singly, i. e. which only constitute an operational entity in conjunction with other parts, this proves to be unworkable for the manufacturer. The certificate required refers to complete installations and equipment ready for operation and can only be given by the installing authority, as the environmental and usage conditions required for the safe running of an installation are known only to that authority (management). The management in charge of the installation or its installation firm has the responsibility to comply with VBG 4. In order to avoid any misunderstanding about the term "manufacturer's certificate" the term "installer's certificate" is used hereafter.

11. Measurement of winding temperature

For particular modes of operation, installations etc., it is necessary to check the winding temperature. Measurements of the housing temperature (e.g. with a contact thermometer) are in general uncertain, as the heat loss between winding and housing depends upon the particular application and installation method, and is therefore not constant. The most reliable indication of winding temperature is obtained by measurement of the resistance change and is determined in the following way: The heating test is carried out with still ambient air or else under the normal operational cooling conditions described, until the reference temperature is attained.

Additionally, the test arrangement should avoid any undue heating or cooling effects.
As the winding temperature follows changes in ambient temperature only slowly, it is essential that the solenoid is exposed to the operational temperature for a sufficient time span before measurement of R_0 commences.

a) Measure the resistance of the cold winding R_0 at ambient temperature ϑ_{10}.

b) The winding is loaded in the previous way to attain steady temperature conditions; (approximately 1.5 hr)

c) Immediately after de-energization of the winding, measure the resistance of the warm winding R_1 and ambient temperature ϑ_{13}.

d) Calculate excess temperature

$$\Delta\vartheta_{31} = \frac{(235 + \vartheta_{10})r}{100} - (\vartheta_{13} - \vartheta_{10})$$

r Percentage increase of resistance

$$r = \frac{R_1 - R_0}{R_0} \bullet 100$$

ϑ_{10} = temperature of cold winding °C

ϑ_{13} = ambient temperature °C, or cooling agent temperature °C

R_0 = resistance of the cold winding

R_1 = resistance of the warm winding

e) The winding temperature is then

$\Delta\vartheta_{31} + \vartheta_{13}$

12. Voltage data

The 24 V and 195 V DC voltages for DC solenoids are the standard voltages. Nowadays, the rectification is mostly executed by silicon bridge rectifiers. With a supply voltage of 230 V AC for example the output voltages amounts to 205 V DC according to IEC 038. Further voltages can be found in diagram 1.

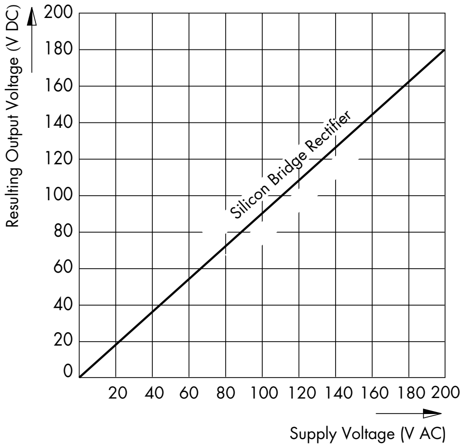


Diagram 1
The diagram shows the resulting DC voltage (arithmetic mean value) when using a silicon full wave rectifier.

13. Relative duty cycle

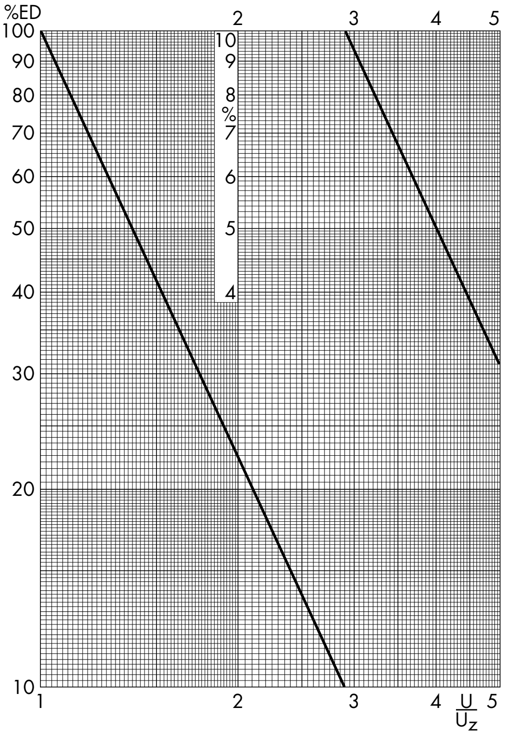
$$\% \text{ED} = \frac{\text{Switch-on}}{\text{operational cycle time}} \bullet 100$$

The operational cycle time results from switch-on period and switch-off period. Our solenoids are designed for an operational cycle time amounting to max. 5 minutes.

Example:
Switch-on period = 10 sec., switch-off period = 30 sec, therefore,
duty cycle = 25 %

This means that you can determine the switch-on time if you know the values of duty cycle and switch-off period.

Example:
Switch-off period = 15 sec., duty cycle = 40 %, therefore, permissible, switch-on period = 10 sec.



14. Deviating duty cycle

In order to achieve a different duty cycle with an existing solenoid (e.g. our preferred types) the operating voltage can be increased accordingly. The dependency of duty cycle and operating voltage is calculated as follows:

$$U = \frac{U_N}{2.162 \sqrt{\frac{ED}{100}}}$$

U = operating voltage
U_N = nominal voltage
ED = relative duty cycle

The diagram enables you to determine the valves very fast.

Example 1:
Existing solenoid
24 V DC, 100 % ED
Desired solenoid 25 %:

$$\frac{U}{U_z} = 1.9$$

24 V x 1.9 = 45.6 V

If the existing solenoid is supplied with 45.6 V the force of a 25 % ED solenoid results.

Example 2:
Existing solenoid 24 V DC, 50 % ED

$$\frac{U}{U_z} = 1.38$$

$$\frac{24\ \text{V}}{1.38} = 17.4\ \text{V}$$

This solenoid can continuously be operated with 17.4 V.

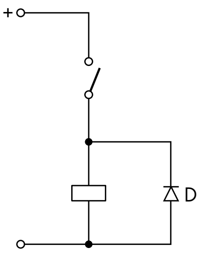
15. Spark quenching

Opening or closing a terminal can result in the formation of an arc or a sparc. The most serious cases occur when inductance is switched off (relais coils, contactor coils, solenoids, valves, connections), resulting in a high switch off induction voltage (up to 20 x rated voltage). The arc or sparc or the switch off induction voltage at the terminal can result in the following detrimental effects.

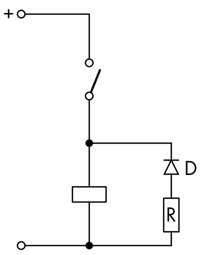
a) contact material erosion
b) contact material migration
c) interference with adjacent electronic systems
d) general interference
e) interference

It is therefore necessary to determine whether steps for arc suppression should be taken. In principle, any means for arc suppression should be applied at the source of the fault and should be tested for optimum effectiveness. It should also be mentioned that arc suppression, in some cases, does not lead to complete elimination of interference, according to regulations.

DC protective circuit:

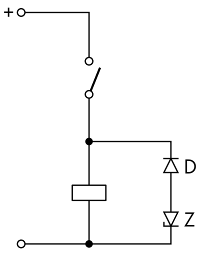


No excess voltage:
Long switch-off delay



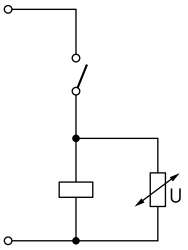
Excess voltage and switch-off delay
influenced by resistor R

Excess voltage and switch-off delay
influence by voltage of zener diode

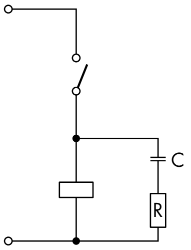


AC and DC protective circuit

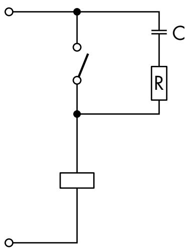
Varistor circuit



RC-circuit of coil



RC-circuit of contact



16. Pull-in time – Drop-out time – Operating frequency

The technical data for the various solenoid version refer to vertical mounting (armature weight against stroke), 100 and 5 % ED without counter force. Small ED causes a reduction in the pull-in time. Additional counter forces or masses cause an increase in the pull-in time. The drop-out time is influenced by the return force and the mass moved. Drop-out times cannot be given in this catalogue since the drop-out force as well as the mass moved are determined individually for each application.

$$f = \frac{1}{\text{pull-in time} + \text{drop-out time}}$$

17. Reduction of pull-in time by increased excitation power

The torque or force output of a solenoid may be increased by momentary over-excitation, thus reducing actuation time. The period of over-excitation must only be long enough for this to occur, otherwise overheating and consequential coil damage can occur. After this period the excitation must be reduced to the permissible value corresponding to the relative duty cycle.

18. Inductance, Time constant

The inductance of a solenoid coil is determined by the dimensions and materials of the magnetic segments as well as the chosen winding. The characteristic factor for any solenoid is the Time Constant τ. The inductance is then given by $L = \tau \times R$. When a range is given in any data sheet, the higher value indicates the time constant for solenoids with windings for 100 % duty cycle and the lower value for solenoids with windings for approx. 10 % duty cycle (with open armatures).

19. Life expectancy

Life expectancy for devices and parts subject to wear in electromagnetic devices, is not only dependent on the design, but mainly on external conditions, e.g. position of device and modes of operation. Therefore indications on life expectancy (requirements and tests) must be determined individually for each particular case.

20. Solenoids according to German and international regulations

Manufacturer's Declaration of conformance (art. 10 EEC Directive 72/73 EEC)

The Kuhnke solenoids listed in this catalogue have been designed and manufactured in accordance with VDE 0580/10.94 and with its addition 0580 d/9.79 following the provisions of the Low Voltage Directive of the European Community as of 19 February 1973.
For international and other national regulations such as CSA, UL etc., we can supply you with a list of the insulation materials used as well as their technical data or their homologation indications (only if required).
Solenoid versions whose order codes begin with HS... or DS... may constitute exceptions from the above declaration since they are fabricated according to customer's specifications.

21. Surface protection

As standard all solenoids are provided with galvanised surfaces. Surfaces without galvanisation are provided with rust proofing on the base of mineral oil.

22. IP protections

In the IEC publications 529 and in DIN 40 050 the modes and degrees of protection for electrical devices are laid down. There are different parts in these regulations:

- protection of persons against the touching of live parts or against approaching such parts as well as against touching of moving parts within devices (housing) and protection of the devices against the penetration of solid foreign bodies.
- protection of the devices against harmful penetration of water

The indication of the protection mode is done as follows:

IP 4 4

Code letter

Protection against touching
and foreign bodies

Protection against water

If the protection mode of one part of the device (e.g. connecting terminal) differs from the main part of the device (e.g. solenoid) the ident Nr. of the differing part has to be indicated as well. The lower protection mode has to be indicated first.

Example:
Solenoid IP 22 – Connecting terminals IP 54

Protection against touching and foreign bodies:

Protective degrees for the first number

First number	Protective degree
0	No particular protection
1	Protection against the penetration of solid foreign bodies with Ø > 50 mm (big foreign bodies). No protection against premeditated access, e. g. hands, however, protection, protection against access of big bodies.
2	Protection against the penetration of solid foreign bodies with Ø > 12 mm (medium-sized foreign bodies) fingers and objects similar to them must not touch the device.
3	Protection against the penetration of solid foreign bodies with Ø > 2.5 mm (small foreign bodies). Tools, wires and objects similar to them must be kept apart from the device if their thickness exceeds 2.5 mm.
4	Protection against the penetration of solid foreign bodies with Ø > 1 mm (grain-sized foreign bodies). Tools, wires and objects similar to them must be kept apart from the device if their thickness exceeds 1 mm.
5	Protection against harmful dust deposits. The penetration of dust cannot be totally avoided but the dust must not penetrate in such quantities that the operation of the device is affected negatively. Complete protection against touching.
6	Protection against the penetration of dust complete protection against touching.

Protection against water:

Protective degrees for the second number

Second number	Protective degree (water protection)
0	No particular protection.
1	Protection against water dropping vertically onto the device. It must not have a harmful effect.
2	Protection against water dropping vertically. It must not have a harmful effect to devices (housing) tipped up to 15° against their normal position.
3	Protection against water dropping in any angle up to 60° of the vertical line. It must not have a harmful effect.
4	Protection against water squirting onto the device from any direction. It must not have a harmful effect.
5	Protection against a jet of water coming out of a nozzle which is directed to the device (housing). It must not have a harmful effect.
6	Protection against heavy sea or a strong jet of water. It must not penetrate the device (housing) in harmful quantities.
7	Protection against water if the device is held under water and if predetermined time and pressure conditions are applied. It must not penetrate the device in harmful quantities.
8	The device can be held under water continuously. The conditions have to be quoted by the manufacturer.