

#### COILS

Coils used in ASCO valves are designed and tested for continuous service. They all meet the thermal endurance specifications according to IEC 216.

Insulation class	Allowable Max. Oper. Temp.	Allowable Max. Temp. Rise	Max. Ambient Temp.	Ref. <sup>(1)</sup>
	(°C)	(°C · °)	(°C °)	
E	120	80	40	-
F	155	80	75	T
		95	60	-
		100	55 <sup>(2)</sup>	T
		100	55 <sup>(2)</sup>	B
		105	50	B
H	180	130	25	F
		80	100	T
		105	75	B
		120	60	-
		120	60 <sup>(2)</sup>	T
		120	60 <sup>(2)</sup>	B
		130	50	F
		155	25	P

Fig. 1

<sup>1)</sup> Additional reference identification letter for coil types : XM5, M6, MXX, M12 (Ex. : FT, FB, FF, HT)

<sup>2)</sup> Catalogue number coils 238xxx-xxx

\* Coil's own temperature rise due to energisation

\*\* Including effect of fluid temperature at catalogue rated limits (Electrical characteristics, solenoid operator's ambient temperature range).

The construction of the majority of coils is in accordance with IEC 335 standards. Other international standards (UL etc.) are also met (contact us).

Standard coils are available for insulation classes E, F and H. The insulation class determines the coil's maximum operating temperature for a specific life:

- Class H: 30 000 hours
- Class F: 20 000 hours

The temperature rise of continuously energised coils depends on size and power consumption. This, in turn, determines the maximum differential pressure rating of a valve as indicated in the catalogue.

An example for insulation class F is given in **fig 1**. The insulation is designed for the coil to be operated at temperatures in accordance with class F, i.e. 155°C. The max. temperature rise of the coil when energised is limited, depending on the type of coil (e.g. 80°C (FT), 95°C, 105°C (FB), 130°C (FF)).



According to the type of coil used, the solenoid operator's maximum ambient temperature (given under "Electrical characteristics" in the specific catalogue pages) including fluid temperature effects may be 75, 60, 50, or 25°C.

Determining factors may be either:

- Temperature considerations (own temperature rise)
- Power considerations
- Ambient and/or fluid temperature
- Higher temperature rise, as result of increased wattage (required for valve pressure ratings).

ASCO offers coils, distinguished by dimension and electrical power: CM5, CM6, CMXX, CM12, CM22, CM25, CM30, CM40, JMX, ANX, AMX, BMX and C22A.

For more details on coils and identification, see Section J / V1100, pages 2 to 5.

#### CALCULATIONS

For direct acting solenoids we can calculate the solenoid pull force by means of the following rough equation:

$$F_s = p \cdot A \text{ (N)}$$

$F_s$  = solenoid pull-force (N)  
 $p$  = pressure (Pa) ( $10^5 \text{ Pa} = 1 \text{ bar}$ )  
 $A$  = orifice area ( $\text{m}^2$ )

#### Example

An average solenoid will have a pull force of approx. 15N. To use this solenoid on a pressure differential of 1MPa (10 bar), we can calculate the maximum orifice diameter.

$$F_s = p \cdot A \rightarrow 15 = 10^6 \cdot A$$

$$A = 1,5 \cdot 10^{-5} \text{ m}^2$$

$$A = 1/4 \cdot \pi \cdot d^2 \rightarrow d = 4,4 \text{ mm}$$

For low pressure applications such as gas burners, automatic dispensing or low vacuum systems up to 0,1 MPa the orifice diameter equals to 19,5 mm.

The internal pilot-operated constructions (floating diaphragm or floating piston) use a small orifice (the pilot) to control the pressure to the diaphragm or piston. Large main orifices can be opened or closed at reasonable pressure up to 15 MPa.

### BASIC DESIGN CONSIDERATIONS

#### The electrical field

To use solenoid as a driver for valves we have to learn first how the magnetism, generated by the solenoid, can be converted into mechanical energy.

If a certain voltage is applied to the coil of the solenoid an electrical current will flow through its windings and creates a magnetic field around the coil.

This field depends on the amount of current, number of windings and length of the coil and can be expressed by the following equation:

$$H = \frac{I \cdot N}{l} \text{ (A/m)} \quad [I \cdot N = \sum H \cdot dl]$$

We discover, however, that the conductance of magnetic field-lines differs for all kind of material.

This conductance is called: permeability " $\mu$ ".

For vacuum the permeability :  $\mu_0 = 4 \cdot \pi \cdot 10^{-7}$  (H/m) or (Vs/Am)

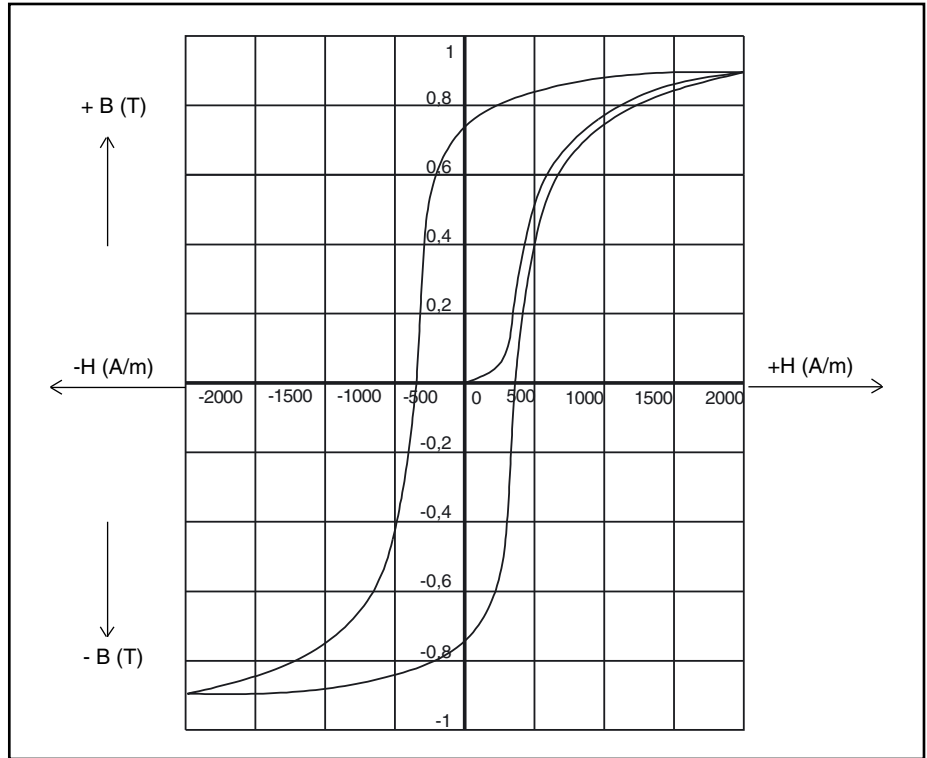
$$\mu = \mu_0 \cdot \mu_r \quad [\mu = B/H]$$

$$\mu_{\text{air}} = 1$$

We distinguish:

- diamagnetical:  $\mu_r < 1$  (bismuth, antimony)
- paramagnetical:  $\mu_r = 1$  (aluminium, copper)
- ferromagnetical:  $\mu_r > 1$  (iron, nickel, cobalt)

To identify the proper " $\mu_r$ " or induction "B" we can make use of the so-called hysteresis-cycle-curves for the ferromagnetical materials.



ASCO's core and plugnut material is special chemical high compatible ferromagnetical stainless steel.

If tables are used, the following equation should be applicable:

$$B = \mu_0 \cdot \mu_r \cdot H \text{ (T)}$$

#### AC and DC Solenoids

As it is important to know the electrical field we have to know therefore the current through the coil.

For DC constructions we can easily calculate the current with the equation:

$$I = \frac{U}{R} \text{ (A)}$$

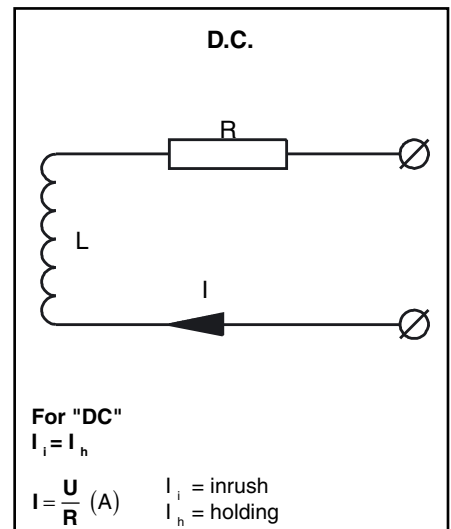
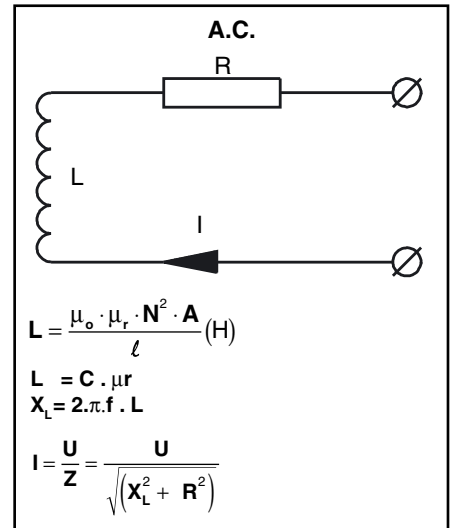
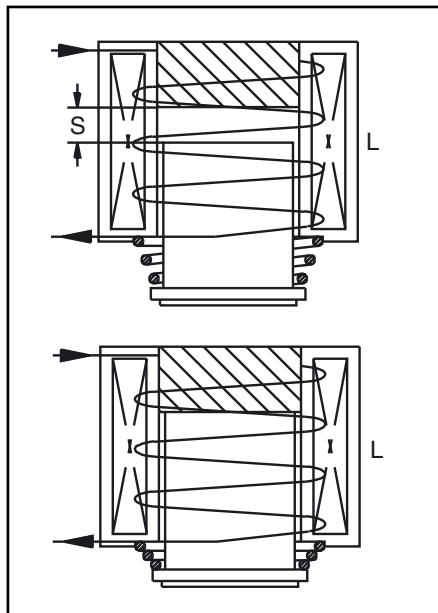
However, for AC constructions we have not only to deal with pure ohmical resistance, but also with AC-resistance, the so-called reactance ' $X_L$ '.

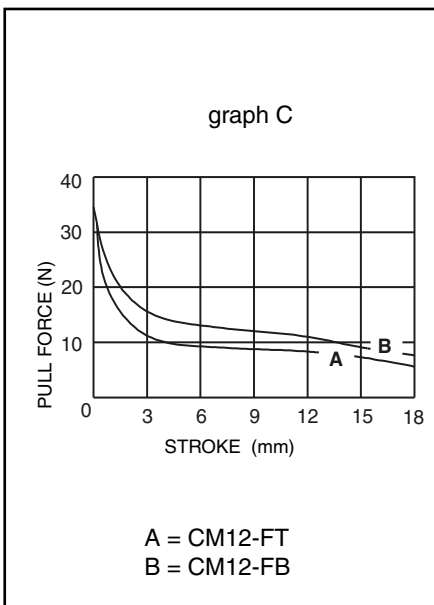
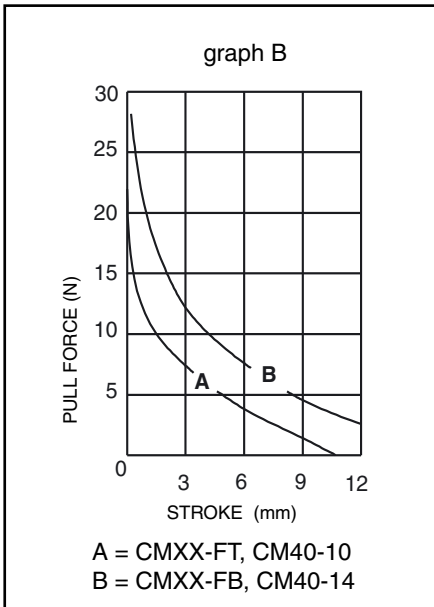
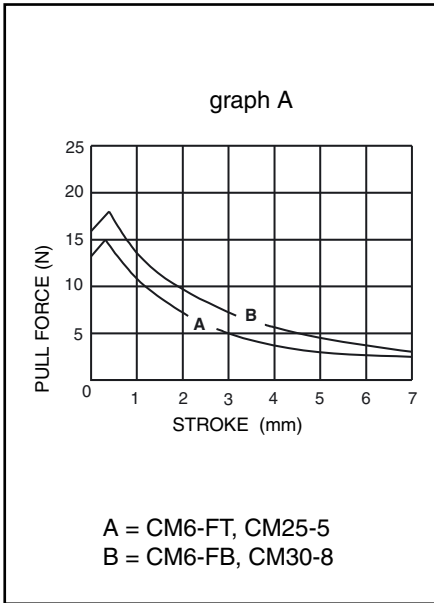
To find the impedance 'Z' we have to combine the ' $X_L$ ' and 'R' values in a vector diagramme. Now we can calculate the current by:

$$I = \frac{U}{Z} \text{ (A)}$$

The ' $X_L$ ' value depends on the air gap between core and plugnut and is smaller when the gap is big.

Therefore we can find a difference between the current through the coil when the core is in its lower position (inrush) and a current with the core in its upper position (holding).





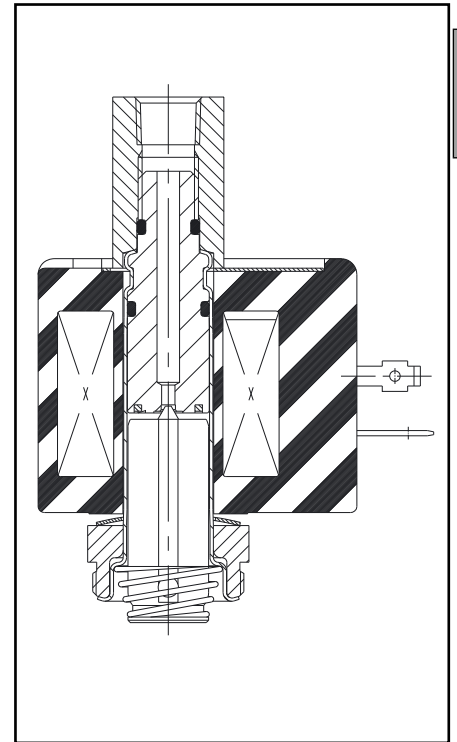
### Pull force of a magnet

With the knowledge of the electrical field and induction we can determine the solenoid driver force by means of the following equation:

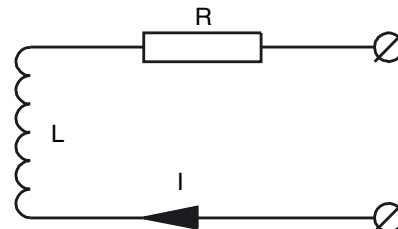
$$F = \frac{B^2 \cdot A}{2 \cdot \mu_0} = \frac{(I \cdot N \cdot \mu_r \cdot \mu)^2}{L^2} \cdot \frac{A}{2 \cdot \mu_0} \quad (\text{N})$$

As the three graphs on the left show, the airgap between core and plunger determines the induction "B" and therefore the pull force "F", the so-called pull-stroke curves do show for each solenoid their typical curves.

- H = Magnetic field strength (A/m)
- I = Electrical current (A)
- N = Number of turns (1)
- B = Magnetic flux density (T)
- $\mu_0$  = Permeability of vacuum (H/m)
- $\mu_r$  = Relative permeability (1)
- A = Area of core (m<sup>2</sup>)
- C = Constant



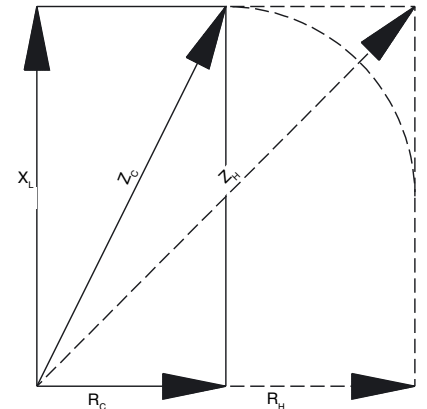
### A.C. (alternating current)



$$R_H = 2 \cdot R_C$$

$$I_C = \frac{U}{Z_C}$$

$$I_H = \frac{U}{1,1 \cdot Z_C}$$

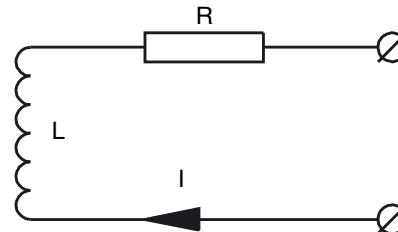


With :

- U = voltage
- $I_C$  = current cold
- $I_H$  = current hot
- $R_C$  = resistance cold
- $R_H$  = resistance hot
- $Z_C$  = impedance cold
- $Z_H$  = impedance hot

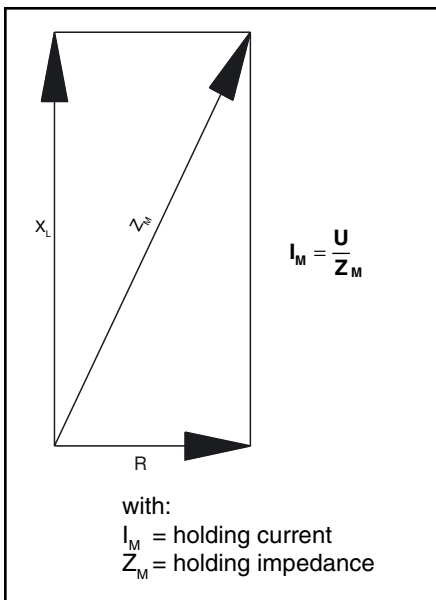
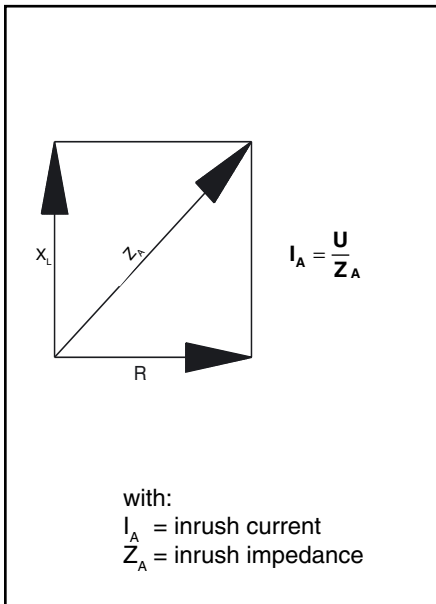
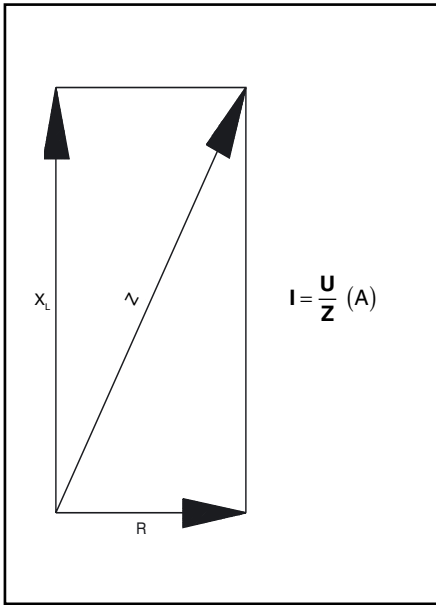
If a coil is heated up in a certain time the coil resistance increases drastically. We can see that to double the coil resistance, when valves are hot, halves the current for DC but only has a minor effect of  $\pm 10\%$  on AC coils.

### D.C. (direct current)



$$I_C = \frac{U}{R_C}$$

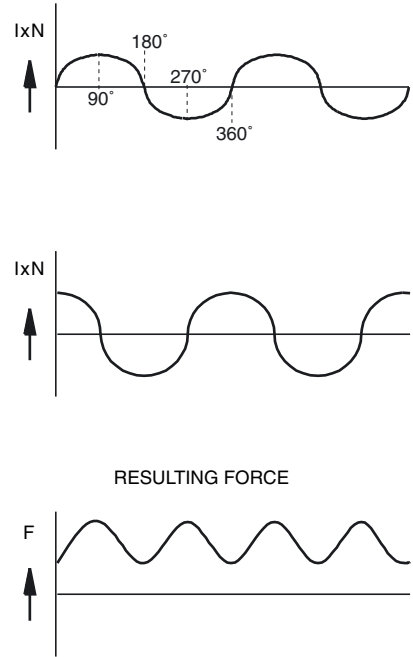
$$I_H = \frac{U}{2 \cdot R_C} = 1/2 \cdot I_C$$



Magnetic field energised by the main coil.

Magnetic field (from the shading coil) generated by the main field, however with a phase shift of approx. 90°.

Combination of the pull forces from main and shading coil.



### Differences between AC and DC solenoids

#### AC service

AC solenoids are always equipped with a shading coil in the plunger (stationary core) and the top of the core is flat faced and perpendicular.

#### DC service

There are two solenoid valve categories: The first category with identical AC and DC design offers easy adaption of the same valve to AC or DC; full interchangeability is ensured for alternating or direct current. The plunger and core of the valves in the second category are conically shaped (choked) and a special non-magnetisable part has to be assembled to prevent sticking of the core in its upper position due to the presence of residue magnetism. This part is called a "breaker piece".

### AC/DC Solenoid comparison

#### AC service

- High inrush and low holding current
- High pull force
- Sensitive to dirt
- The coils have less windings (copper) than DC coils
- Power consumption and pull force not sensitive to temperatures.

#### DC Service

- Inrush current equals to holding current
- Power consumption and pull force depend on temperature
- Solenoid operates quietly
- Not sensitive to dirt
- The coils have more windings (copper) than AC coils

#### Power Consumption for AC:

$$P^{(W)} = U \cdot I \cdot \cos\phi$$

$$I_A^{(A)} = \frac{P_A^{(VA)}}{U^{(V)}}$$

$$I_M = \frac{P_M^{(VA)}}{U^{(V)}}$$

with :

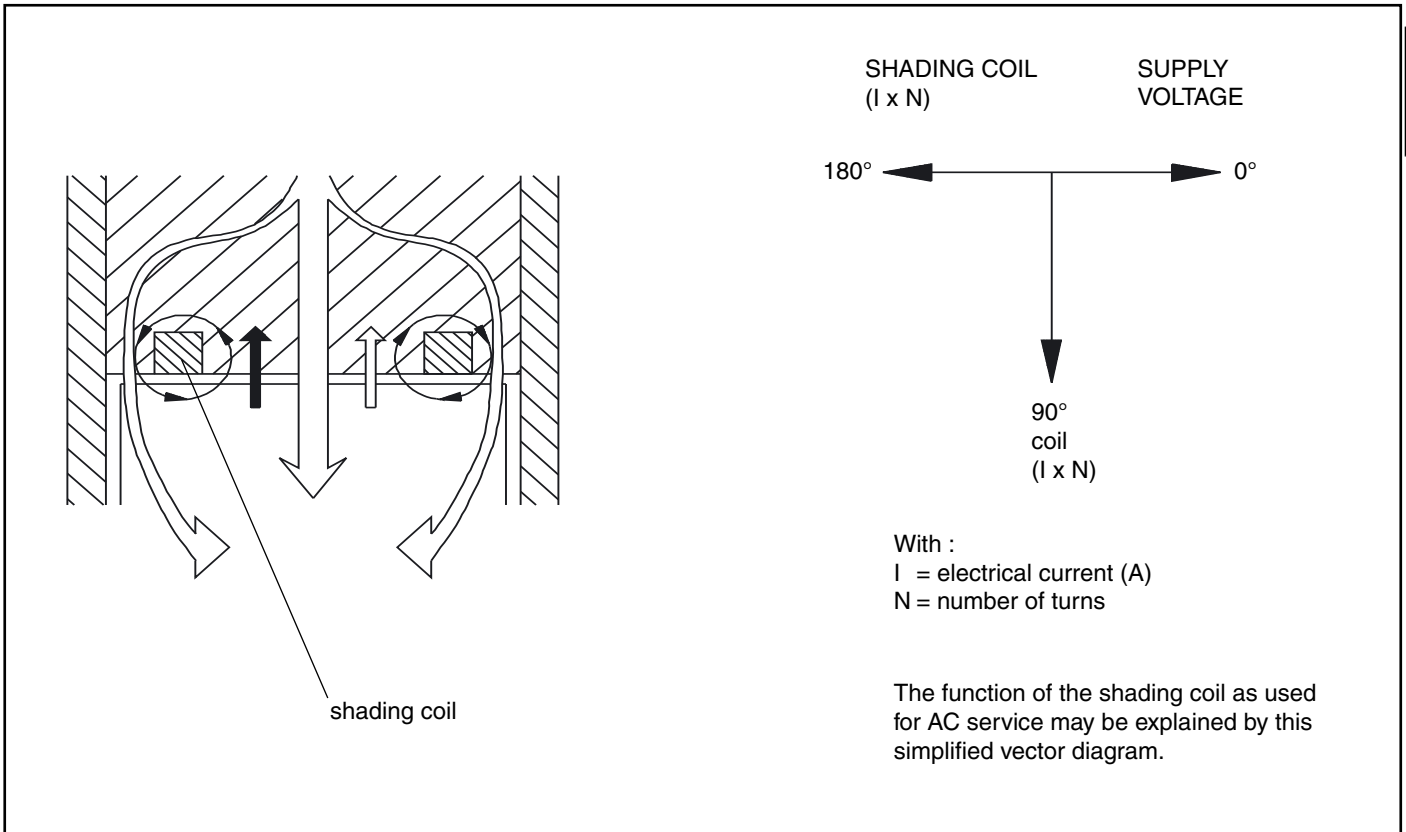
$P_A$  = inrush VA value

$P_M$  = holding VA value

#### Power Consumption for DC :

$$P^{(W)} = U \cdot I$$

$$I^{(A)} = \frac{P^{(W)}}{U^{(V)}}$$



### NOMINAL POWER RATINGS

The nominal power ratings indicated in the "ELECTRICAL CHARACTERISTICS" tables are average values and are based on measurements on standard products. In most cases the tables show values for cold and hot conditions. The definitions below have to be recognized.

#### Cold nominal power ratings

This value in watts represents the amount of power dissipated by the coil system after connection to the power supply. In this case the coil has the same temperature as the ambient or, in some situations, the temperature of the medium handled. The above results in a nominal cold coil resistance. The cold coil resistance is lower than the hot coil resistance thus resulting in a higher power rating under cold condition than under hot. In practice the cold nominal power rating has to be taken into account when a solenoid valve is operated (for the first time).

#### Hot nominal power ratings

After a certain period of time the coil system is warmed-up and reaches a final operational temperature. This period of time may differ, depending on solenoid construction, voltage variation, ambient temperature, valve size and piping system, from 1 to 5 hours of operation. The above results in a nominal hot coil resistance. The hot coil resistance is higher than the cold coil resistance thus resulting in a lower power rating under hot condition than under cold. In practice the hot nominal power rating has to be taken into account when calculations are to be carried out for cost or lifetime battery applications.

#### General remarks

The cold and hot power ratings are defined under normal operation conditions i.e.:

- nominal supply voltage (Un)
- ambient and medium temperature 20°C

Please note that the following may influence the values given:

- supply voltage variation (see Section J/pages 2 and 3 for details)
- ambient temperature
- medium temperature
- the size and type of the piping system.

