Introduction

According to the U.S.A.S.I. (United States of America Standards Institute) a relay can be defined as: An electrically controlled device that opens and closes an electrical contact to effect the operation of other devices in the same or another circuit. Relays are an important factor in today’s industrial processes.

More than 25 billion relays operate today all over the world as an interface between electrical control circuits and electrical loads. Technical progress has lead to miniature-sized relays in mono-, bi- and tristable executions which need only a little or even no supply voltage to produce high contact power.

Function of a relay

A relay fulfills two fundamental tasks:

- Galvanic separation (insulation) between the control section and the switching section.
- The switching of power loads with high voltage and/or high current by means of low power consumption (low voltage/low current) even as low electrical signals.

There is a very wide application field for relays. Where electronic and electromechanical conditions of use need to satisfy the above mentioned conditions, a relay is required, e.g. for control equipment, timers, temperature control, signal control and so on.

There are two different kinds of devices:

- The electromechanical relay and the electronic relay (Solid State Relay, SSR)

In an electromechanical relay, a high insulation condition exists between open contacts when the device is switched. On the other hand with the SSR this is not the case. This means a different approach to safety problems. However, the SSR has no contact bounce (no moving parts) and very low pick-up times. In addition, the ratio between device cost and switched power is much higher in the SSR than in an electromechanical relay.

The SSR is suited for particular applications in which high switching frequency is important without contact wear.

Main parts of a relay

An electromechanical relay composes two different devices or parts: an electromagnetic and an electrical switch.

The first is the control section and the second the switching section used to be directly applied to the electrical load. The electromagnet makes a conversion of an electrical current into a magnetic flux which generates a force to move the switching part.
Electromagnet

Fig. 1 shows a classic electromagnet configuration with the four basic parts:
The coil: This consists of one or more copper wire windings, usually wound over a bobbin made of an insulated material. The ferromagnetic core.
The ferromagnetic joke.
The ferromagnetic moving armature.

Additional parts:
- Contact springs: (Contact blades) fixed and movable
- Contacts
- Push-bar
- Contacts and coil pins
- Contact support base
- Dust cover

Fig. 1 Classical electromagnet configuration

Switching section

The classic switching section configuration is formed by one change over contact scheme. In the following explanation, this example will be used since it is the basic scheme to which all the others may be referred. Fig. 3 shows a switching relay section with one change over contact. There are:
- the normally closed contact fixed blade (NC)
- the movable contact blade
- the normally open contact fixed blade (NO)
- the push-bar
- the insulation contact support base
- the soldering contact pins

Fig. 3 Relay switching section

Bistable relays

A bistable relay is a relay which, being activated by an input energizing quantity and having changed its conditions, remains in that condition after the quantity has been removed. Another energization is required to make it change over to the previous position.

A further division of categories could be made according to the function, such as:
- All or nothing
- Step by step
- Polarized
- Remanence
- Reed relays

All or nothing relays

This term identifies monostable relays which are intended to be energized by a quantity whose value is either:
- higher than that at which it picks up
- or lower than that at which it drops out (IEC)

This relay category has to be supplied with a definite range of voltage (or current). It can be activated by supplying or removing voltage (or current) within the prescribed range.

Step-by-step relays

This is a relay with two or more rotary positions moving from one step to the next in successive operations by means of an impulse of the activating quantity. Normally it operates its contacts by means of cams.

Remanence relays

A remanence relay responds to a power supply, changes its condition and remains in that position after the supply has been removed.

An additional supply is required to reset the relay. The heart of a remanence relay is the core, which is made of a special magnetic iron that, after a voltage impulse, keeps itself permanently magnetized. It has a nickel base with additions of aluminium, titanium or niobium (55 - 85% Co, 10 - 12% Ni).
Relays
General information

Switching section Cont.

Function:
Starting condition: OFF status

Supplying the coil with DC voltage impulse \( V_i \), chosen from the prescribed supply voltage range and having a duration \( t_i \), the electromagnetic field grows immediately causing the core to be magnetized and the relay activates (NO contact closes). When the impulse stops, the relay remains permanently in the ON status due to the permanent magnetization of the core. (Fig. 4)

Fig. 4 Remanence relay, electrical circuit

Therefore it has a magnetic polarization depending on voltage supply polarity. Now to switch the relay to the OFF status, it has to be supplied with an opposite polarity to change the magnetic polarization of the core.

Changing only the supply polarity, the relay will not drop out. For the relay drop out, the polarity has to be changed and the value of the power supply must be inferior to the value of the activation.

Application circuit

There are two different types of remanence relays:
- One winding remanence relay with external drop out resistance for current limitation, e.g. MZ.R1 (Fig. 5).

Fig. 5 Application circuits for one winding remanence relay (Vers.R1)

These relays can also be supplied with AC voltages due to an external diode which rectifies the AC voltage with a minimum duration impulse of 10 ms (half period). Remanence relay performance is equal to that of the normal versions.

- Remanence relays with two windings and two different voltage ranges for ON/OFF operation, e.g. Feme type MZ.R2 (Fig. 6)

Fig. 6 Application circuits for two winding remanence relay (Vers.R2)

Polarized relay

This is a relay with a permanent magnet giving additional magnetic force which leads to lower power consumption. There are monostable and bistable versions. The supply quantity must be with the right polarity according to the polarity of the magnet; this is the reason why it is named “polarized relay”.

Reed relays

The dry reed relays have the great advantage of being hermetically sealed and are thus impervious to atmospheric contamination. They are very fast (10 to 20 times faster than electromechanical relays) and when operated within the rated contact loads, they offer a reliable switching component and extremely long life. The basic element of the reed relay is the glass reed capsule commonly known as a reed contact.

Fig. 7 Reed contact

A reed contact consists of two overlapping, flat, ferromagnetic reeds, separated by a small air gap, sealed in a glass capsule. The reeds are supported at the point where they are sealed into the ends of a glass tube and therefore act as cantilevers. If the free ends of the reeds are...
placed in a magnetic field, the flux in the gap between the reeds will cause them to pull together. When the magnetic field is removed, the reeds will spring apart due to the spring tension in the reeds. The reed capsule blades thus provide a magnetic operating gap and serve as a contact pair to close and open an electrical circuit.

**CM and CST series (reed relays)**

**CM**
- dual-in-line reed relay
- up to 2 normally open contacts
- DC coil supply
- available with diode across coil for electronic protection
- relay for PCB mounting
- available with electromagnetic protection

**CST**
- Reed relay for PCB mounting
- up to 5 NO contacts
- DC coil supply
- sealed (coil) and unsealed versions
- available with electromagnetic and electrostatic field protection

**Relay types produced by Carlo Gavazzi Feme**

**Miniature relays for PCB mounting, M series**
- bistable and monostable versions
- normal, flux-free and sealed versions
- DC and AC coil supply
- 5 to 16 Amps contact rating up to 2 change over contacts
- versions 4KV/8mm reinforced insulation

**Flat-pack miniature relays for PCB mounting, F series**
- normal, flux-free and sealed versions
- DC coil supply
- contact rating up to 10 Amps
- up to 4 change over contacts
- versions with 4KV/8mm reinforced insulation

**Industrial and mini-industrial relays for PCB mounting, on sockets, wire soldering, fast-on terminals, R series**
- with and without dust cover
- DC and AC coil supply
- up to 16 Amps contact rating
- up to 4 change over contacts
- versions with 4KV/8mm reinforced insulation and contact gap > 3 mm (only NO contacts)

**Subminiature relays**
- subminiature relays for PCB mounting
- normal and sealed versions
- DC coil supply
- contact rating 50mA - 5A
- up to 4 change over contacts
- high sensitivity

**Calculation of pick-up and drop-out voltage**

The above parameters are significantly affected by the change of ambient temperature. The resistance of the copper wire depends on the temperature according to the following law:

It increases or decreases by 4% for each 10°C temperature variation.

Example:

- Coil resistance
  \[ R = 1400 \quad \Omega \pm 15\% \]
- Pick-up voltage
  \[ V_p = 21 \quad VDC \]
- Drop-out voltage
  \[ V_D = 1.8 \quad VDC \]

The above values refer to 20°C. Question: Find the same values at 70°C ambient temperature.

Answer:

- Pick-up voltage at 70°C:
  At 70°C (given by)
  \[ R_{30} = R_{20} \times 1.20 = 1400 \times 1.20 = 1680 \quad \Omega \]
  \[ V_{30} = V_{20} \times K_1 \]

where \( K \) is the resistance variation coefficient due to temperature variation

So \( V_{30} = 21 \times 1.20 = 25.20 \quad VDC \)

**Formula:**

\[ V_T = V_{20} \times K_{1T} \]

**Fig. 8 Minimum operating voltage variation according to ambient temperature**

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Where there is a project temperature limit of TL materials, the relay must be used so that $T_c$ will be inferior to $T_L$ ($T_c < T_L$).

There are two different ways to limit the $T_c$ value:

- limitation of the maximum ambient temperature;
- limitation of the coil power dissipation by limiting the maximum supply voltage (also the power dissipation of the contact section affects this phenomena)

Since, as a rule, the temperature range is theoretical, we can only set the maximum voltage to get the right overtemperature of the coil. As minimum voltage is referred to a temperature of 20°C, so also the maximum temperature is referred to 40°C. The law that rules the reduction or the increase of the maximum voltage on temperature change is experimentally determined and depends on dimensions, materials, shapes of the relays. For example, Feme M series relays have a $K_2$ coefficient that must be used as a multiplication factor for the maximum voltage,

\[ V_T = V_{40} \times K_{2T} \]

Question: The maximum allowable voltage at 10°C and 60°C for the following relay:

- $R_c = 2700 \mu F \pm 15\%$
- $V_{\text{max}} = 34 \text{ VDC}$
- $V_{\text{max}} = 55 \text{ VDC}$

Note: Min. voltage is referred to 20°C
- Max. voltage is referred to 40°C

Answer:

- $V_{\text{max}} 10^\circ C = V_{\text{max}} 40^\circ C \times K_{2 10^\circ C} = 55 \times 1.12 = 61.6 \text{ VDC}$
- $V_{\text{max}} 60^\circ C = V_{\text{max}} 40^\circ C \times K_{2 60^\circ C} = 55 \times 0.88 = 48.4 \text{ VDC}$

Note: Two other considerations must be made:

The maximum voltage limit is determined by the above heating problems and also by the magnetic iron saturation of the electromagnetic circuit.

$K_1$ and $K_2$ are not given for all relays. If this is not specified, it can be assumed that the voltage range is to be used for the whole ambient temperature range. The reason why these values do not appear in the data sheets is that these relays have a wider margin towards the supply voltage limits due to their physical structure.

### Calculation of pick-up and drop-out voltage Cont.

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### Switching section: Main schemes and mechanical solutions

There are different contact scheme configurations to solve the various needs of the appliance problems: Normally open contacts (NO), normally closed contacts (NC) and change over contacts are the basic configurations used to draw all relay contact configuration schemes. By using these basic contacts, we can construct many relay configurations to succeed in solving the problems of appliances. The only theoretical limits are relay dimensions, electromagnetic power, switching power and drawing complications. The contact switching combinations available on a relay are defined in terms of number of poles, number of throws (single or double), normal position (open or closed contacts), and the sequence to make and break. Abbreviations used to define the exact nature of the contacts are as follows:

- SP = single pole
- ST = single throw
- NO = normally open
- NC = normally closed
- B = break
- M = make
- DP = double pole
- DT = double throw

and so on

Another classification is also used by some relay producers (e.g. Feme). The code is the following: $X, Y, Z$

- $X =$ number of NO contacts
- $Y =$ number of NC contacts
- $Z =$ number of change over contacts

For example, we can have the following situation:

- 100 = SPST-NO (1-form A)
- 010 = SPST-NC (1-form B)
- 001 = SPST = 1d (1-form C)
- 200 = DPST-NO (2-form A)
- 020 = DPST-NC (2-form B)
- 002 = DPST = 2d (2-form C)

and so on
Contacts and contact shapes

Contact pressure
When two contacts close to make the electrical continuity, they touch each other on a contact area depending on the shape of the contacts. The contact force (N), measured on contact axis, divided by the contact surface (mm) is the contact pressure (N/mm). In practice, it is impossible to know the real contact surface area because it also depends on contact surface irregularities. Contact pressure means contact force. To achieve high contact surface area, contact force must be increased to deform the contact surface irregularities. Low force means few effective contact points and low contact area (high contact resistance).

Cylindrical contact rivets
Cylindrical contact rivets are normally used in bimetallic, massive or other versions, like the contact parts of miniature relays, due to their optimum switching performances and their facility in process assembling. Contact coupling is normally between a fixed contact, with a plane surface and a movable contact (common contact), with a spheric surface. As a rule, the common contact is a massive rivet and the fixed contacts (NC and NO, when speaking about a changeover configuration) are bimetalic (Fig. 11). The head of the central massive contact is preformed on one side and the other is formed during the assembly process of the contact with the blade. The plane-spheric coupling between contact surfaces is needed to reduce coupling area increasing the contact pressure. Moreover, there is a relative surface movement (rolling) that is useful to improve contact performances (Fig. 12).

Low profile contact
A stamped strip of metal or contact alloy is automatically welded on the blade strip material before the blanking process. During the blanking operation the contact strip is cut together with the blades and it is also coined to give the intended contact shape (Fig. 13). This solution is useful to avoid dangerous voltage drop-out in the junction between blade and contact. This gives the opportunity to choose the proper contact shape.

On the other hand, higher force increases the number of contact points also the total contact area (lower contact resistance). Contact force can only be increased as far as the mechanical strength of the parts and the operating voltage sensitivity will allow. Relay manufacturers use different contact shapes according to relay design solutions and product applications.
**Cross bar contacts**

Using low profile contacts, a contact coupling with cylindrical surfaces can be designed with perpendicular axes. In this way, limited contact surface and high contact pressure can be obtained. Moreover, during switching operations the two contacts work like “two knives” keeping a very clean contact area.

**Fig. 14 Cross bar contact**

**Twin contacts**

In some appliances (low level signals - safety systems) to increase the contact reliability, twin contacts are used. There are rivets or low profile contacts put side by side on the same bifurcated blade (fixed and movable blades). So, doubling the contact points can halve the failure probability.

**Fig. 15 Twin contact**

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**Contact Materials**

Contact materials and special alloys have a great importance in switching problems and each appliance needs the correct evaluation of the electrical load ambient conditions and other information to make to right choice.

**Surface finishing**

Precious contact materials are largely used for their high conductive properties but, especially silver and its alloys suffer from superficial corrosion due to sulphurous impurities in the atmosphere (SO₂ - sulphur dioxide). This superficial attack forms sulphur layers on contact surfaces that are very harmful to contact resistance. These materials can be covered with a gold layer or with other noble metals (metal having high resistance to corrosion and/or oxidation: platinum, palladium, and so on).

**Cleaning**

Cleanliness is of great importance in the relay assembling process in order to keep the internal relay parts free of dust and other particles, that can interpose between contacts, impeding correct switching operation. Therefore, contacts, semi-worked parts and, in some applications, the whole relay (without dust cover) immediately before its closure are washed.

**Plastic pollution**

Due to the effect of temperature, the internal plastic parts of a relay may emit gases and vapours. If they cannot be emitted, they may be deposited on the contact surface increasing the contact resistance. This is especially the case with sealed relays in which, without previous special plastics treatment, it can be very dangerous. This treatment consists of a hot degasifier process in which plastics are caused, at low atmosphere pressure, to emit gases and vapours. At the end of this process, the ambient pressure is established by nitrogen to avoid, inside the relay, chemical reactions due to the presence of humidity and oxygen.

**Contact resistance and influence**

The electrical contacts have the main task to close an electrical circuit to carry a current (I) with a voltage (U). This “simple” fact requires some special characteristics of the contacts depending on materials, shapes, mechanical parameters, etc.. When the current (I) flows through an electrical circuit, the circuit resistance (R) is opposed to current flow based on the law:

\[ U = R \times I \]

The R value is composed of two different resistances: The circuit Rc and the relay contact resistance Rr. So we have \( R = R_c + R_r \), and \( U = I \times (R_c + R_r) \).

The dissipated power \( P_{tot} \) by the whole circuit is

\[ P_{tot} = P_c + P_r = (R_c + R_r) I^2 \]

**Fig. 16 Basic circuit**

Normally the circuit resistance value \( R_c \) is distributed in an uniform way on the circuit length (cables, wires, PCB and so on) and \( P_c \) is dissipated in the same way (low temperature increase); on the other hand, \( R_r \) is entirely concentrated inside the relay (temperature increase problems). That shows the great importance of keeping relay contact resistance as low as possible. This is important in power applications as well as in low level ones (low voltage, low current); in the first case, we have the temperature rise problem inside the relay; in the second case, high contact resistance is dangerous for the correct performance of the appliance.
Question:
Find the power dissipation (W) values in the relay contact circuit with the following circuit conditions:
Electrical load: I = 5A, U = 250VAC
Relay contact resistance (mΩ):
   a) 10mΩ
   b) 50mΩ
   c) 300mΩ

Answer:
a) RC x I² = 10 mΩ x (5A)² = 0.25 W
b) RC x I² = 50 mΩ x (5A)² = 1.25 W
c) RC x I² = 300 mΩ x (5A)² = 7.50 W

This shows that with high contact resistance, the power dissipation inside the relay reaches undesired levels.

Question:
Find the voltage decrease caused by the relay contact resistance in the following circuit with these conditions:
Electrical load: I = 1mA, U = 5mV
Relay contact resistance:
   a) 10 mΩ
   b) 100 mΩ
   c) 400 mΩ

Answer:
Voltage drop across contacts is:
a) RC x I = 0.01 x 0.001 = 0.01 mV
b) RC x I = 0.10 x 0.001 = 0.10 mV
c) RC x I = 0.40 x 0.001 = 0.40 mV

High resistance values cause an appreciable percentage voltage reduction that can be dangerous in some appliances. It is important to note that, normally, high contact resistance also means contact resistance instability. For low level applications signals (measurements and so on), the resistability of the contact resistance value is a fundamental requirement. Contact resistance is influenced by the following factors:
- contact pressure
- materials
- surface finish
- cleaning
- internal pollution of plastic relay parts
Each single influence must be considered.

**Alloys and contact materials**
The choice of the contact material depends on the application. The most commonly used contact materials are:

**Silver**
Pure silver (Ag 99%) has the highest electrical and thermal conductivity of any known metal and shows good resistance against oxidation but is affected by sulphur presence in the atmosphere. This produces silver sulphide that increases contact resistance. To avoid this problem, the surface is covered with gold (5µm) because this metal keeps itself free from silver sulphide (no chemical reaction). This is the right contact version widely used for low level switching from µV to 24 VDC and AC and from µA to 0.2 A and, in any case where there is no arc presence that can destroy the gold layer exposing silver to the harmful sulphur presence.

**Silver cadmium oxide**
(Ag 90% - CdO 10%) has a wide range of applications in power loads due to its good performance against contact sticking (welding) and arc suppression effect. Its application range is from 12 to 380 VAC and from 100 mA to 30 A. It is especially used for resistive and inductive loads such as motor loads, heating resistors, lamp loads, solenoids and others. This material is a standard material that covers most customer needs. It suffers from sulphide problems but the presence of arc and relative high voltage and currents make this problem negligible (arc and voltage perforate sulphide layers).

**Silver-nickel**
(Ag 90% - Ni 10%) is the most suitable alloy to switch DC loads to avoid material migration that occurs in DC with medium currents and voltages (1 - 10 A; 6 - 60 VDC). This is a physical phenomenon that, owing to DC current influence, induces material transfer from one contact to the other (from cathode (-) to anode (+)). This rapidly causes contact wear and dangerous contact gap reduction.

**Tungsten**
This is the hardest material with high resistance against contact sticking but has a relatively high contact resistance. Owing to these characteristics it is normally used in electrical circuits, where high current peaks of short duration occur, to avoid contact welding: Capacitive loads, motor loads, lamp loads (especially fluorescent ones), etc. The application range is 24 - 500 VAC and 0.5 - 5 A (current peaks of hundreds of amperes).

**Electrical relay life**
The electrical life, or switching life, is the minimum number of cycles that a relay is able to perform under particular conditions of current, voltage, operating frequency and ambient temperature, where “cycle” is a complete switching operation, starting from OFF status to ON status and back again to OFF status. The end of the electrical life occurs when the contacts are not able to switch the electrical load within contact resistance values (or contact voltage drops) that, becoming higher, stops the regular switching operations (the limits depend on application). In relay specifications, electrical life is given in the following way: Number of cycles at nominal current - nominal voltage - stated frequency and ambient temperature.
Electrical relay life Cont.

E.g. for relay type MZP 002 46 05, the electrical life is:
Number of cycles: $2 \times 10^5$ at 5 A - 250 VAC - 50 Hz resistive load 1000 cycles /hour - ambient temperature 70°C.

In practice, customers also require the electrical life at lower current values. So by means of laboratory tests, an electrical life curve is ascertained in which there is electrical life values (cycles) function of the electrical load current (Fig. 18).

The diagram shows the electrical life of a relay with resistive electrical load in AC at a specific switching frequency and 250 VAC - 50 Hz. E.g. the electrical life of an MZP 200 48 05 with a resistive electrical load of 3A - 250VAC - 50 Hz is about 350,000 cycles. The inductive loads introduce high contact wear that reduces the relay contact life. This reduction, experimentally determined, is given by a multiplying factor for resistive electrical life (depending on the load power factor cosine) that must be used to determine the expected life.

Question:
What is the electrical life for relay type MZP 001 46 05 with the following electrical load: 3A - cosine 0.4 - 250 VAC; 1000 cycles/hour should be determined. Diagram Fig. 18 shows that, with resistive load (cosine = 1), the expected life is about 500,000 cycles. Diagram Fig. 19 illustrates that, with power factor cosine = 0.4, a reduction coefficient of about 0.65 is achieved. So the expected electrical life under the above conditions will be: $500,000 \times 0.65 = 325,000$ cycles.

Switching in AC and DC

Different problems are involved in switching AC and DC electrical power loads and different aspects must be considered to understand the matter. In AC circuits (about 50 - 60 Hz frequency) when relay contacts open, they may do it on two possible voltage load conditions with regard to voltage sine and arc phenomena (see Fig. 20).
Sometimes arc suppressor circuits are used to reduce this effect: Resistor and capacitor placed across the load.

The following law governs the relation among U, I, R and C:

\[
C = \frac{I}{10} \quad (\mu F)
\]

\[
R = \frac{E}{10 \left(1 + \frac{50}{E}\right)} \quad (\Omega)
\]

where

- \( E \) = Source voltage just prior to contact closing
- \( I \) = Load current just prior to contact opening
- \( \alpha = \left(1 + \frac{50}{E}\right) \)

\( C \) = Value in F of the capacitor
\( R \) = Value in Ohm of the resistor

This circuit is useful with AC and DC inductive loads:
- Across the contacts, fig 21a): for Source Voltage ‘E’ more than 100 V. (Impedance of RC must be negligible compared to load impedance if used for AC source voltage).
- Across the load, fig 21 b): for Source Voltages ‘E’ less than 100 V (AC and DC)

DC switching is affected by two main

**Arc interruption**

In DC appliances, the arc interruption is a critical problem, because voltage does not cross the zero value like in AC. So when the electrical arc occurs, only contact gap and contact material properties contribute to arc extinction. Relays have normally a physical limit, depending on the above parameters, that make them unable to switch the load with currents and voltages higher than the specific values. These values are expressed by means of a curve that gives the maximum switching power (U x I) with resistive and inductive loads L/R value of the timing constant is given \( L = \text{inductance (Henry)}, \ R = \text{resistance (Ohm)} \).

As a rule, we give a L/R 40 ms (milliseconds) for the inductive loads that is a medium value in appliances. Example: (Fig. 24) The maximum allowable DC switching currents for MZP 100 49 05 at 180 VDC
with resistive and inductive loads are 250 mA and 150 mA respectively. Under these values we are sure that the arc is extinguished. Also for AC inductive appliances the suppression circuits are useful.

**Specific loads**

**Filament lamp loads**
The contact closure on filament lamp loads (tungsten lamp) creates problems due to the high current peaks connected to the filament low resistance when it is cold. For example, a 60 W-220VAC filament lamp has a "cold" resistance of about 60 Ohm that corresponds to a current of 3.66 A (it lasts a few milliseconds). On the other hand, the hot lamp has a current of 0.273 A (there is a 15:1 ratio). This illustrates the big stress in lamp switching for the contacts (danger of welding and sticking). When switching a lamp load, the following has to be considered:
- maximum lamp load
- contact material
E.g. for MZP A 001 45 10 with AgCdO contacts, the maximum allowable lamp load is about 1100 W corresponding to 5 A at 220 VAC. In other appliances with higher loads, alternative materials or relay techniques are used (tungsten, AgSnO2).

**Motor loads**
Motor loads are inductive loads that show a particular behaviour when switched on. A current peak occurs due to the rotor inertia that is connected to the mechanical load applied to it. A locked rotor may have up to 6 times the rated current. Moreover, when it is switched OFF, we also have the damaging effect caused by inductive loads. So the right contact material choice is connected to the above load characteristics especially if a capacitor is connected to the motor. AgSnO2 and tungsten contact materials are especially used for this application. Normally the motor load is expressed in HP (horse power), where 1 HP is equal to about 745 Watts. Example: MZP A 001 41 10 has a motor load rating of 3/4 HP.

**Capacitive loads**
This is the heaviest contact load to be switched ON due to the high inrush current peak that occurs when the capacitor is discharged (like a short-circuit). The peak intensity may reach hundreds of amperes for a short time (micro-milliseconds) that must be supported by contacts. The contact sticking problem may be avoided in two ways:
- use of Tungsten contacts
- reducing the current peak by introducing a current limiting resistor
The same problem occurs when closing contacts with a charged capacitor: A violent discharge results.

**Switching time and contact bounce**
When supplying a relay coil for opening and/or closing, this operation will happen in a time depending on electrical and mechanical inertia of the parts. The delay which elapses between the coil supply impulse and the steady contact closure or/and opening is the sum of the influence of the electromagnetic group and the switching section.

**Electromagnetic group**
The current flows through the coil with a delay caused by the coil inductance that opposes itself to current flux. Moreover, the movable parts such as the armature and push bar oppose their mass to the movement caused by the magnetic flux.

**Switching section**
The elastic forces stored in contact blades and springs and their elastic deformations are opposed to the movement of the relay parts; also the inertia of the contact masses affects this phenomenon. As a rule, the delay times for miniature relays reach values of some milliseconds (5-15 ms) in pick-up operation and few milliseconds (1-5 ms) in drop-out. In the drop-out phase the operating time is shorter due to the absence of the negative magnetic circuit delay. In fact when taking off the supply voltage from the coil terminal, the current flowing through the coil wire stops immediately and the relay drops out by means of the elastic energy stored in the contact blades.

**Fig. 25** Pick up operating time

**Fig. 26** Drop-out operating time

**Bounces**
In drop-out and pick-up phases when contacts close, they never make this operation in one time but the collision between the two contacts causes them to rebound. "Contact bounce" causes a continuous contact closing and opening. This affects especially contact performance such as electrical life and signal switching.
Sine vibration

An electromechanical relay is strongly influenced by dynamic phenomena that may change, permanently or temporarily, its intended characteristics. Appliances, in which vibrations occur, must be deeply examined to know the entity and quality of the stress. Tooling machines, car appliances, assembling machines, and generally each appliance in which the drive electronics are affected by the presence of movable parts (motors, vibrators, valves, etc.) may suffer from this problem. To test relay performance in vibration conditions, Carlo Gavazzi Feme usually subjects it to sine vibration test at a constant acceleration (G) in a specific frequency range. Moreover, the relay is tested on its three body-axes (x, y, z) and for each axis in the two principal directions. As a rule, relays are tested with the PCB mounting (sockets and materials, etc.).

Tests are performed in two steps: Resonances research and fatigue test. The relay is tested in energized and deenergized coil conditions. Contact continuity is monitored by an oscilloscope with a low level load on the contacts. After its test, the frequency range (Hz) and the maximum acceleration value can be defined to which the relay can work without losing contact continuity (interruption 10 µS) or without suffering permanent damage. For miniature relays, standard values (which satisfy a large field of appliances) are 10 G at 25 to 100 Hz. These values are the worst case, normally obtained in the most critical test conditions (deenergized relay on particular stress axis). In low frequency range tests (few Hz) instead of constant acceleration, a constant displacement corresponding to a specific acceleration value is simulated (e.g. 10 to 25 Hz of 2.5 mm. p.p. amplitudes. The test frequency at which a change from constant displacement to constant acceleration takes place is termed "cross frequency". For example, at 55 Hz 10G correspond to 1.5 mm p.p.

Shocks

For miniature relays, a standard value is 10G, for maximum peak acceleration, and 11 ms, for the pulse duration. As for sine vibrations specimen ohm test must also be conducted for shock in the OFF and the ON status, in the three body-axis (x-y-z) and, for each axis, on the two principal directions. Three shocks forewarn condition must be applied. The tested relay must not open contacts (interruption 10 µS) and, at the end of the test, it must be working perfectly.

Hermetical relays - soldering and cleaning

The necessity to use sealed or hermetrical components in appliances has two different reasons: Protection of internal parts (contacts, mechanisms, wires) against penetration of flux in the soldering and cleaning process and protection of the internal parts against environmental pollution.

Soldering process

Modern electronic technology widely uses automatic soldering processes for the mounting of components on PCB's. That allows soldering of the whole circuit in one step. This "wave soldering process" consists of a melted tin-lead alloy (60 % - 40 % or 63 % - 37 %) that, in a special machine, is caused to perform a wave that touches the lower circuit side soldering components pins with the copper circuit tracks. Before this operation, the circuit is wetted by a liquid (flux) that helps the soldering operation taking off the copper oxidation. There are many different kinds of flux, made of organic and inorganic acids but all may be less or more dangerous for the internal parts of the relay, and also for the other components. So, after the soldering process, it is important to wash the circuit. The commonly used cleaning methods are: Hot water, fluorocarbon liquids with or without the use of ultrasonics (u.s.). It is obvious that materials involved in relay construction parts (dust cover, sealing resin, printing inks), directly in contact with cleaning chemical, must be able to be physically and chemically resistant against them. For each particular application, it is important to know and, sometimes, to test the compatibility between relay and chemical products.

Environmental pollution

The relay working ambient may adversely affect the relay's performance. Moisture, industrial air, dust and particles getting inside the relay may affect contacts, internal parts and insulation. Environmental conditions in which relay and appliance will be used should be analyzed in order to avoid problems such as contact resistance increase and metallic part corrosion.

If the ambient conditions are not so arduous and/or the electrical contact load is not critical (cleaning presence of arc) it is better to open the relay after the soldering and washing process allowing a useful exchange between internal and external atmospheres. This is important for thermal exchange (high switching powers), emission of gas caused by switching arc and residual plastic pollution. As explained before, the relay sealing process includes a plastic degasifying process, internal filling with inert gas (nitrogen) and closing process with labels or other methods.


**Hermetic test**

The "bubble test method" (according to MIL STD 883 B Method 104 - C condition) is a testing procedure to check the relay hermetically. The relay is dipped into fluid (distilled water or inert fluid) at a specific temperature (70 - 85 °C) for 1 minute. Test is successful if, during this period, no bubbles escape from the relay. This testing procedure simulates the real cleaning process stress to which relays are submitted.

**Dielectric strength**

Dielectric strength or insulating strength are the parameters giving the ability of a material or an insulation to withstand in keeping an electrical separation between two parts. This characteristic is expressed in kV (1 kV = 1000 V) and it is measured applying an AC voltage at 50 Hz to 60 Hz between the concerned parts. A leakage current flows between them, but, if it does not exceed the value of one mA (for convention), it is not considered as a failure in insulation. The test must be performed for 1 minute. An accelerated test of 1 second duration is allowed but we must increase the test voltage by 10%. The value of the dielectric withstand voltage is influenced by the following parameters:
- air distances
- air humidity
- superficial distances (creepage distances)
- insulating material characteristics
- metallic conductor shapes

**Insulation resistance**

Another parameter giving a measurement of insulation performance between two conductive parts is the insulation resistance. This is the electrical resistance of insulation materials to an impressed DC voltage producing a leakage current through the surface of these materials. Low insulation resistance values may permit high leakage current affecting the insulation between the parts (safety and/or high impedance circuit problems). Applying a testing DC voltage of 500 VDC with a Mohen M meter (also 100 VDC test voltage) between the insulated parts gives an insulation resistance value expressed in MΩ (10^6 Ω). Insulation resistance is very important in appliances in which safety requirements are indispensable such as medical equipment and all the appliances strictly connected to direct human contact. See section Insulation on Feme Data Sheets.

**Impulse voltage test**

The impulse voltage test consists of applying a voltage impulse between two insulated electrical parts to prove the ability of the relay to withstand, without damage, overvoltages of high value and very short duration. Overvoltages may sometimes occur due to incorrect circuit working or in presence of atmospheric discharge (lightning). These phenomena may be harmful to the electronic control circuits and especially to people's safety. An impulse of a specific voltage (Feme uses 5 kV to 10 kV or more) is applied between the parts simulating a lightning discharge with the following parameters:
- front time: 1.2 µs ± 30 %
- time to half-value: 50 µs ± 20 %

Three positive and three negative impulses must be applied at intervals of not less than 5 s. The pulse shape is shown in Fig. 28.

The voltage impulse is normally performed between the low voltage section (electromagnetic group) and the switching section. It is rarely performed between open contacts and/or different switching sections.

**Capacity between the parts**

The capacity is measured between: Open contacts, different contact sections, contacts and coil and frame and coil. These capacities might influence the behaviour of the electrical circuits in which the relay is applied. The use of a relay in circuits means the introduction of low capacity values (few pF) among different circuit points. So the maximum allowable values of capacity accepted by them must be known especially for high frequency appliances and measurement apparatus in which a small change in projected capacity values might cause equipment failure and malfunction.

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**Specifications are subject to change without notice**