TECHNICAL INFORMATION

Definition and Operation

Solenoids are electro-mechanical devices used to convert electrical energy into linear mechanical motion. Electrical current passing through the solenoid produces a magnetic field which, in turn, creates an attractive force between a movable plunger connected to an external load and a fixed backstop. If this attractive force is greater than the external opposing force of the load, the plunger will move toward the backstop when the solenoid is energized and the motion is transmitted to the load. When the solenoid is deenergized, the plunger is returned to its original position by the force of the load or by a return spring which can be part of the solenoid assembly.

Mechanical connection from the load to the movable plunger can be made at either end of the plunger. If the connection at the end opposite the backstop, the solenoid is a pull type. If the connection is made by a rod through the backstop to the inner end of the plunger the solenoid is a push type. Figure 1 illustrates the two types of solenoids.

Solenoids can also be classified by the construction type as open frame, box frame, or tubular. These construction types are listed in the order of increasing cost, and the choice between the types would be based on the customer's requirements for size, mounting, environmental protection and magnetic efficiency.

Solenoid Selection Factors

The following mechanical, electrical, and thermal factors must be considered in the selection of a solenoid to perform a specific function in a satisfactory, reliable, and economical manner.

1. Force/Stroke Characteristic @ operating conditions
2. Duty Cycle
3. Ambient Temperature
4. Size Limitations and Mounting
5. Input Power Type and Availability
6. Type of Electrical Connectors
7. Environmental and Life Considerations

Force and Stroke Characteristics

The operating force required throughout the length of stroke must be determined for the particular application involved. With this information, the solenoid force-stroke illustrated in this catalog can be used to select a basic solenoid type.

The pull force required by the load must not be greater than the force developed by the solenoid during any portion of its required stroke. (See Figure 2) If the pull force required is greater than the force developed by the solenoid, the solenoid will not pull in completely and fail to move the load the required distance. In AC solenoids, this can also cause the coil to overheat and melt down.

Mechanical Life

Maximum solenoid life is achieved when the pull force required coincides as nearly as possible with the force generated by the solenoid. Solenoids which develop substantially more force than is required are subject to excessive hammering which eventually can cause mechanical failure. To improve mechanical life, load must be in line with the plunger and side loads must be kept to a minimum. Mechanical life in DC solenoids will be increased with the addition of an anti-bottoming feature. There will be a reduction of forces due to increased internal air gap when an anti-bottoming feature is included.

Plunger Shape

The shape of the internal end of the plunger influences the force-stroke characteristic of a given solenoid. This shape can be varied to meet particular requirements. In DC applications a conical shaped plunger is most commonly used. A comparison of two solenoids equivalent in every way with the exception of the shape of the plunger faces will show that a flat plunger will produce a large force through a short stroke while a conical shaped plunger will produce more force at a longer stroke. Figure 3 illustrates the influence of various plunger shapes on the slope of the force-stroke curve.

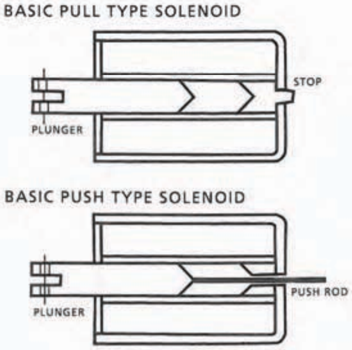

FIGURE 1

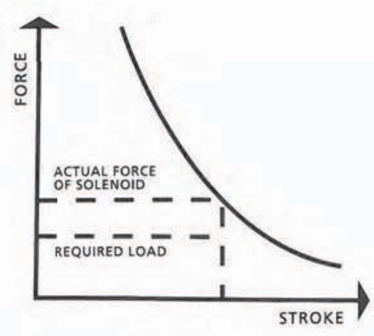

FIGURE 2

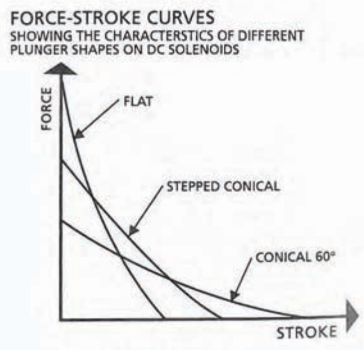

FIGURE 3

AC solenoids usually use flat faced plungers with a shading ring either in the plunger or the stop. AC solenoids provide higher force at longer strokes than identical DC solenoids due to higher in-rush current. AC solenoids shown in this catalog are designed for 60 Hz. operation. At other cycles (50, 400, etc.) the coil characteristics must be revised. A 60 Hz. coil will have greater current drain and higher heating at 50 Hz. Load alignment and side loading are more critical on AC solenoids than on DC solenoids. Side loading or misalignment will slow the plunger and cause overheating and possible melt down. AC solenoid plungers must seat completely to prevent overheating and possible melt down. For this reason, anti-bottoming features should never be included in the design.

Duty Cycle

Most of the electrical energy supplied to a solenoid appears as heat in the solenoid coil. Because of this, the length of time that the solenoid is energized is a major factor influencing the coil temperature. Duty cycle expresses the proportion of time that the solenoid is energized in a given time period.

Duty cycle in percent equals the on-time divided by the sum of the on-time plus the off time x 100, as expressed by the following formula:

$$\text{Duty cycle (\%)} = \frac{\text{time ("on")}}{\text{time ("on")} + \text{time ("off")} \times 100}$$

Input Power Type and Availability

The application will determine the available type of input power. DC power is preferred for most applications because of flexibility in design, reliability of the solenoid, quiet operation, and consistent operating speed.

Magnet-Schultz of America can supply a bridge rectifier as part of the solenoid assembly where operation of a DC solenoid from AC power is necessary.

A continuous duty solenoid is designed for operation in the energized state for an indefinite period of time.

An intermittent duty solenoid is actuated for a short period of time and then allowed to cool. An intermittent duty solenoid will have a higher power input and produce much greater force for size and weight than its continuous duty counter-part. Magnet-Schultz of America U-frame and box-frame intermittent duty solenoids are rated for 1 minute "on maximum" and 3 minutes "off minimum". The cylindrical units are rated at 1 minute "on maximum" and 9 minutes "off minimum".

A pulse duty solenoid will require even greater input power, but will produce even greater force than the intermittent duty solenoid. Magnet-Schultz of America pulse duty solenoids are rated at 100 milliseconds "on maximum" and 900 milliseconds "off minimum".

Operating Temperature

For maximum service the temperature of the solenoid coil should not be permitted to rise above the temperature rating of the insulation. Most standard Magnet-Schultz of America solenoids use Class B (130°C) insulation. Higher temperature class solenoids are also available. Applications requiring these devices should be referred to the factory.

The combination of ambient temperature, power input, and duty cycle determine the operating service temperature of a solenoid in the final application. The method of mounting the solenoid is part of the ambient temperature consideration.

Most Magnet-Schultz of America standard solenoids are Class B (130°C) based on a 25°C ambient temperature with the solenoid mounted on a 6" x 6" x 1/8" steel heat sink, in still air.

It is good practice to measure the operation temperature of the coil in the actual application to be sure that it does not exceed the maximum temperature rating of the solenoid.

Size Limitations and Mounting

Many solenoid applications provide only limited space for the solenoid itself. The application may also dictate a particular method of mounting the solenoid. These factors must be considered in the selection of a solenoid for a given application.

The method of mechanically connecting the load to the solenoid plunger should be selected to minimize any radial loading (side load) on the plunger. Radial plunger loading will cause performance deficiencies and excessive wear. The connection method is usually influenced by the application requirements.

The information required concerning input power for a particular application includes power type (AC or DC), input voltage, and maximum available current.

Type of Electrical Connections

Electrical power can be supplied to the solenoid through a variety of types of connections. Common types are leadwires, .187 inch quick connect terminals or 0.025 square pin terminals. Pin terminals for direct soldering to printed circuit boards, for connection to multiple cavity sockets, or solder terminals for hard wiring into the final circuit. Terminal, lead location and length can be varied to suit a specific application. Magnet-Schultz of America has designs that incorporate molded coils with built in integrated connector interlocks.

Consult with the factory for special connection requirements.

Environmental and Life Considerations

Depending on the application, various methods can be employed to protect the solenoid from a hostile environment.

All metal parts of the solenoid are protected by plating.

The coil in a tubular solenoid is completely encased in metal. The coils in an open-frame or box-frame solenoid are usually protected with electrical grade tape, but can be protected with acetate yarn, varnish, or encapsulation in plastic. Consult with the factory for the appropriate coil protection for special applications.

In applications where low friction and long life are critical, special materials can be used on the surface of the plunger and the surface of the plunger cavity. Consult with the factory concerning the suitability of these materials in a specific application.

Underwriters Laboratories Recognized materials are used in the construction of Magnet-Schultz of America standard solenoids.

Engineering Design and Testing

The use of a standard or semi-standard solenoid design will usually result in the most economical component. However, in those cases where the customer's requirements preclude the use of a standard unit, Magnet-Schultz of America offers complete custom design services. Magnet-Schultz of America maintains an engineering and testing laboratory which is equipped to measure and graph force-stroke characteristics, temperature rise, and operating time, as well as conduct other special tests on solenoids for custom applications.