Solenoid Technical Information

A. Definition and Operation:

Solenoids are electro-mechanical components which convert electrical energy into mechanical work. This manual provides information on solenoids which produce linear motion - push and pull.

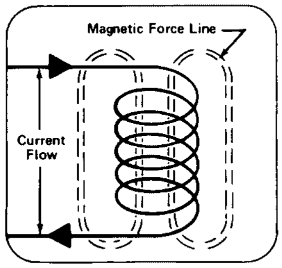

Fig. 1

Current passing through a helical coil winding of closely spaced turns of copper magnet wire produces a magnetic field which surrounds the coil. (Fig.1) If an iron structure is assembled around the winding, the magnetic force is channeled through the metal and is considerably increased because of the magnetic **permeability** of the iron. (Fig. 2)

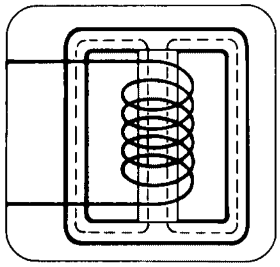

Fig. 2

B. Construction:

(Fig. 3) A standard solenoid is constructed with a core, inside the coil, made of two sections - a fixed pole piece, or backstop (A), a movable armature or plunger (B), and an iron frame around the coil winding (C). The magnetic lines of force created by the electric current in the coil react to close the gap (D) between the plunger and backstop; the plunger moves and generates a linear force - **mechanical work**. The magnetic **permeability** of the plunger, backstop and frame will dictate the efficiency of the solenoid. Also, it is important that magnetic force lines disappear when the coil is de-energized; any remaining is called **residual magnetism** and may prevent the plunger from returning to the position it had before current was applied to the coil. Solenoid design providing a negligible **residual magnetism** characteristic is essential.

The movable plunger is held in position in the center of the coil winding by a guide (E) which may be made either of non-magnetic metal or plastic.

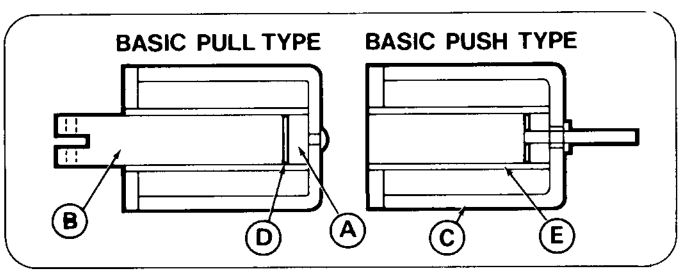

Fig. 3

Fig 3 shows a typical solenoid construction with a **flat faced** plunger-backstop mating surface. This is always incorporated in A.C. solenoids, but D.C. units may have parts with conical shaped mating surfaces. (Fig. 4)

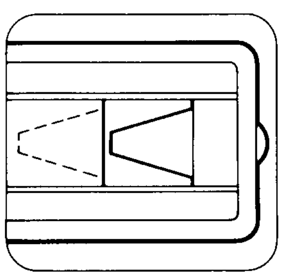

Fig. 4

C. Performance:

One of the most important parameters to be considered in solenoid selection is the **force-stroke** characteristic. This performance data is represented in this manual by a series of curves for each of the solenoids listed. For most applications, the minimum force required is at the **beginning** of the plunger movement, or stroke. As the plunger moves from this starting point, the force it develops increases at a rapid rate until it reaches its maximum value in the “O” gap or seated position.

All solenoids develop magnetizing force, which has a relationship to the current and number of turns in the coil. In an A.C. powered solenoid, the amount of current passing through the coil will vary depending on the plunger position. (Fig. 5) Because the current at the stroke starting point is significantly higher (called **inrush** current) than the “O” gap (**rated** current), it generates a higher initial magnetizing force than will be present as the plunger seats against the backstop. Thus, the slope of the force-stroke curve is generally less steep than for a conventional D.C. solenoid (Fig. 6). A similar reduction in the slope of this curve can be obtained with a D.C. solenoid equipped with a **conical** shaped plunger-backstop combination. Generally a 40° taper is used for the maximum force over a relatively long stroke.

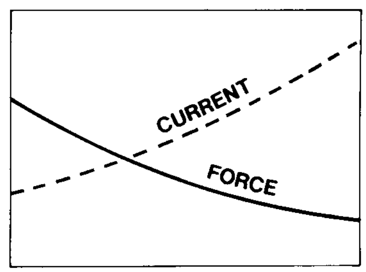

Fig. 5

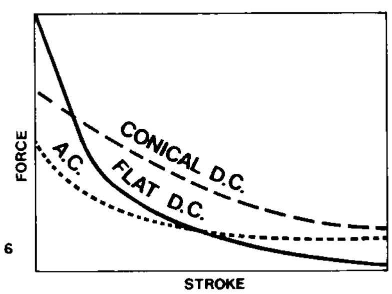

Fig. 6

Solenoid size determines the amount of work a solenoid can perform. A large unit will develop more force at a given stroke than a small solenoid (with the same coil current), because its greater physical volume will **accommodate** more turns of wire on the coil. It is important that a solenoid selected for a particular application have a rated force as close to the load requirements as is possible. Too much force reduces solenoid life because the unit must absorb the excess energy. If the force is too low, the result will be unsatisfactory performance because the plunger will not pull in or seat properly. In an A.C. solenoid, the lack of force may cause a high noise level or possibly coil burnout because of excessive current.

S. Selection Factors - Ratings:

1. Voltage - Standard values are listed for both A.C. and D.C. types. The 100% voltage, 25° C curve represents the maximum force output, while the 85% (80% for D.C. units) 105° C curve indicates the minimum force generated under the combination of low voltage and high coil temperatures. In most applications this minimum curve must be considered the "design-curve" by the application engineer who must make allowances for the derating effects of anticipated voltage drops and increases in coil temperatures.

2. Duty cycle - Specifies the length of time the solenoid coil is to be electrically energized and de-energized. Standard units are made in three categories: **(a) Continuous** - coil can be energized indefinitely; **(b) Intermittent** - coil is energized for short intervals and cut off for periods long enough to allow the winding to cool. This duty cycle permits application of higher coil power than in (a), and provides considerably more force. Deltrol intermittent-duty solenoids are made with three ratings: 1/2 min. ON, 1-1/2 min. OFF for the very small sizes; 1 min. ON, 3 min. OFF for the medium sizes; and 3 min. ON 9 min. OFF for the larger sizes. (See individual data sheets.) The ON time figures are maximum; OFF times minimum. If a special intermittent duty cycle is required, **both** ON and OFF times must be specified; **(c) Pulse** - coil is energized just long enough for the plunger to complete its stroke - usually up to 100 milliseconds. OFF time must be a minimum of 900 milliseconds. This duty cycle rating provides solenoids with the maximum useable force consistent with the size and style of the unit. Pulse duty type windings made to particular specifications are generally used in circuits called "pick-and-hold" and "power-surge". In the former, a high voltage is applied to the solenoid coil to provide the maximum pull-in force the unit can provide and, when the plunger is seated, the voltage is dropped to a value for continuous duty power operation. Because the pick voltage applied is of such short duration, it can be supplied from a capacitor discharge. With a power-surge circuit, the current can be automatically switched from a high power to a low power coil (included in the same solenoid) or a series resistor can be switched in the circuit after the pull-in has been completed.

3. Current and Power - Selection of solenoid means coil requirement must not exceed output of power source or rating of operating switch. For A.C. units, inrush current must be considered. A solenoid, as a power load, is usually highly inductive.

4. Temperature - All standard "C" and "D" frame type solenoids incorporate Class A rated insulation. Operating data furnished is for a maximum coil temperature of 105° C (25° C ambient - 80° C coil heat rise). If a higher ambient is encountered, the coil must be derated, the duty cycle adjusted or the insulating materials used in the coil construction upgraded. When higher than normal temperatures are encountered, a Deltrol application engineer should be consulted for the most practical solution which may include one or all of the above-mentioned options.

E. Selection Factors - Operation:

1. Stroke - Distance plunger must travel. Generally considered in two parts. (a) Pretravel - plunger movement before load is picked up; the greater the pretravel, the more momentum generated and a higher starting force will be exerted. (b) Working stroke - portion of plunger travel during which applied load is moved. Plunger stroke is generally limited by the application; however, a stroke limiting attachment may be included in the solenoid. Total stroke should be kept to a minimum to utilize greatest force produced by solenoid; also, the wear factor is less and inrush current is kept low in A.C. solenoids keeping down heat rise.

2. Force - Pull or push energy developed by plunger when coil is activated. Normally, the most important force measurement is at the start of the stroke, where the plunger picks up the load. In some applications, other stroke positions are equally important and solenoid size selection is determined by this criterion. Proper alignment of load to plunger travel is important. Side thrusts on plungers will cause excessive wear and increase noise of A.C. units. The load should never prevent plunger from seating on A.C. solenoids.

3. Mounting and Environment - Since coil heat rise is detrimental to the maximum efficiency of a solenoid, the type of mounting and free air movement around the coil is important. The force curves shown in this manual illustrate the operation of all solenoids at 25° C and 105° C (or 130° C) coil temperature. The coil temperature rise, at rated duty cycle, can be kept below the limit by mounting the solenoid on a good heat sink and avoiding a confined space. The advantage of keeping coil temperature as low as practical is self-evident. When a solenoid is used in an application that generates a high ambient temperature (over 40° C), a special coil winding is required incorporating either a lower than standard power rating or class B, F or H rated insulation. A Deltrol sales engineer should be consulted for such applications.

4. Codes and Standards - Practically all of the solenoids listed in this manual are designed to meet NEMA standards and the requirements listed under the Components Recognition Program of Underwriters Laboratories. Most of the "C" and "D" frame solenoids are designed to meet applicable U.L. specs and may be used in equipment requiring U.L. approval, provided the U.L. requirements for the specific application are observed.

F. Optional Special Features Available:

Many popular "special type solenoids" are available. Illustrations of some of the available options are shown on pages 66 & 67 of this manual. When an application requires a special or custom solenoid, it is important that complete data on the usage be submitted for design purposes. A solenoid data sheet questionnaire is included in the back of this catalog - and assistance from a Deltrol Sales engineer is always available.