WHAT IS A SOLENOID?

Prepared by

Decco®

to promote a better understanding of the basic operation of AC Industrial Grade Solenoids

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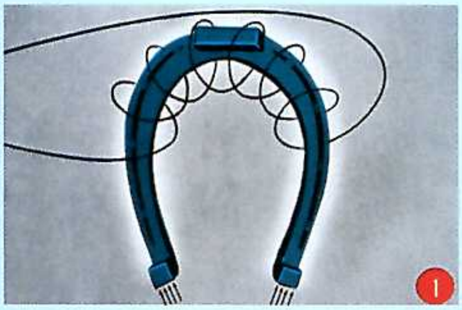
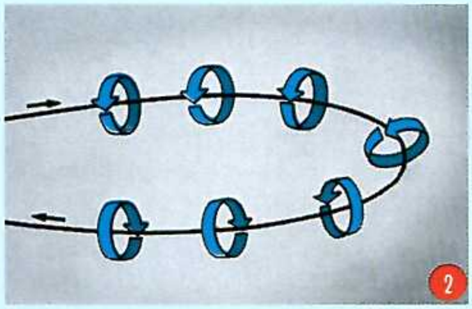
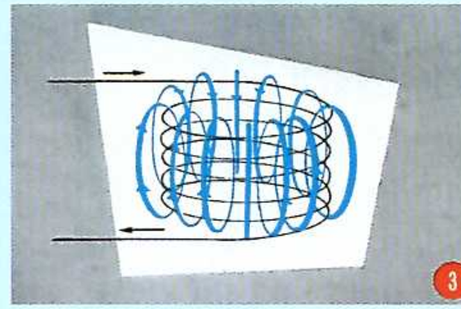


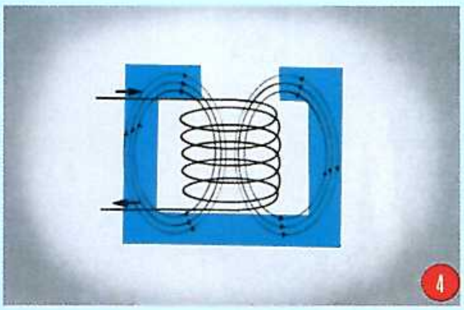
A solenoid is simply a specially designed electro-magnet. Here's how it works.



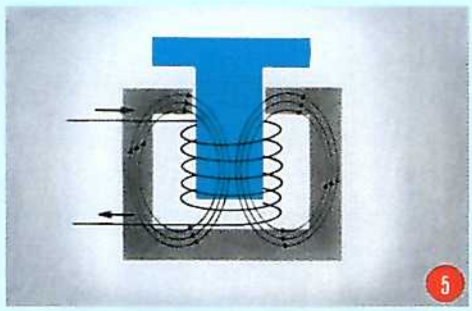
When current flows through a wire, a magnetic field is set up around the wire.



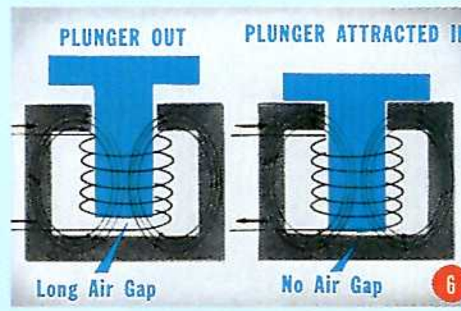
If we make a coil of many turns of wire this magnetic field becomes many times stronger, flowing around the coil and through its center in a doughnut shape.



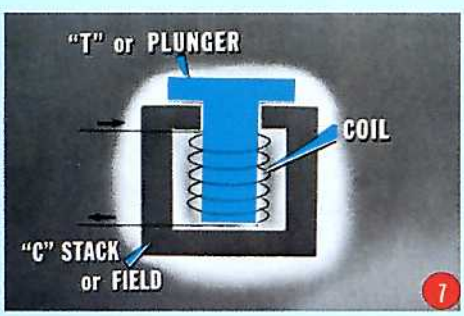
Although this magnetic field will flow in air, it flows much more easily through iron or steel – so we add an iron path, or "C" stack around the coil which concentrates the magnetism where we want it.



If we also add an iron path, known as a "T" or plunger, in the center of the coil, the magnetism is concentrated still more.

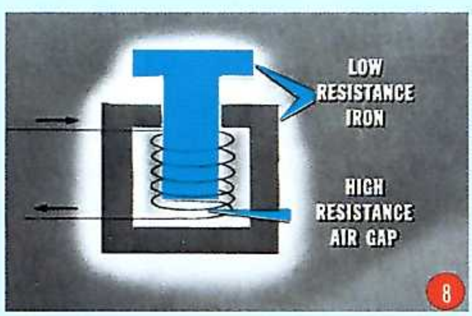


Because iron is an excellent magnetic conductor and air is a poor one, the movable iron "T" or plunger is drawn by the magnetic field into a position where the magnetism can travel 100% through the metal conductor.

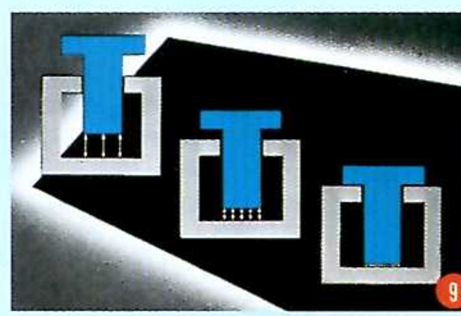


With the addition of this movable plunger we have the basic solenoid as it is today.

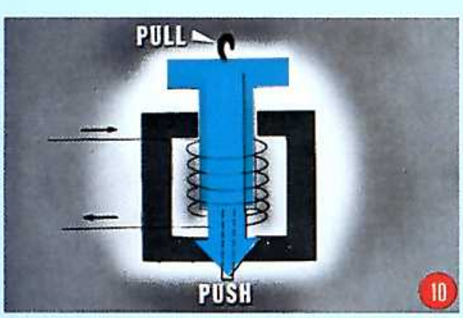
Now, let's look at some refinements.



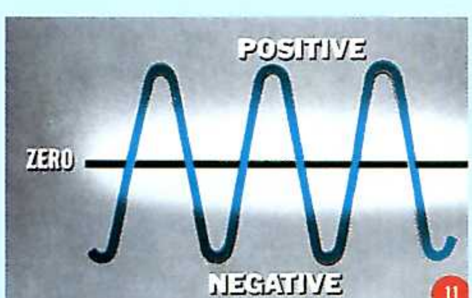
Remember, a solenoid operates because the magnetism tries to reduce the high resistance air gap at the bottom of the plunger. When the plunger is completely closed, the magnetic field flows 100% through a low resistance iron path.



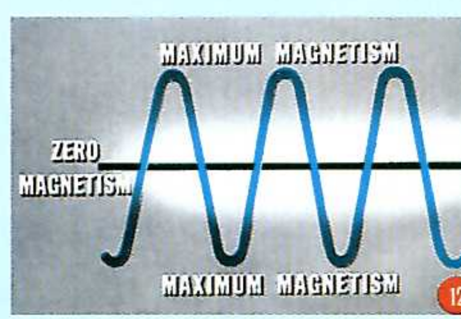
As the plunger is pulled into the coil, the air gap under the plunger is reduced, making the magnetic field stronger and increasing solenoid force. So ... as the solenoid closes, it becomes more powerful.



We have shown that a coil's magnetic field provides motion in only one direction – into the center of the coil. How, then, can we get a push and pull action? To pull, we simply hook on to the top of the plunger. We push from the bottom of the plunger.

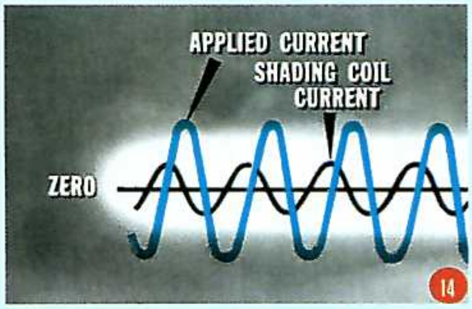


An A.C. solenoid operates on current which looks like this. It alternates from positive through "zero" to negative sixty times a second.

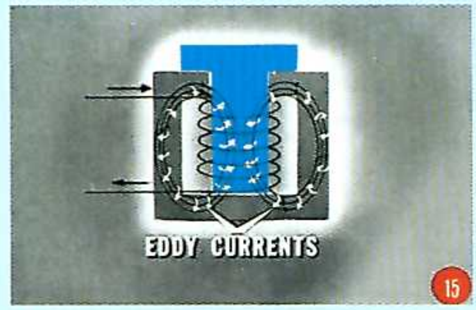


The magnetic field is strongest when the alternating current is at its positive and negative peaks. As the current goes through zero, the magnetism and solenoid force decrease, and the load forces the plunger out. When magnetism and force build up again, the plunger is pulled back in. This motion of the plunger, in and out, makes the solenoid buzz or chatter.

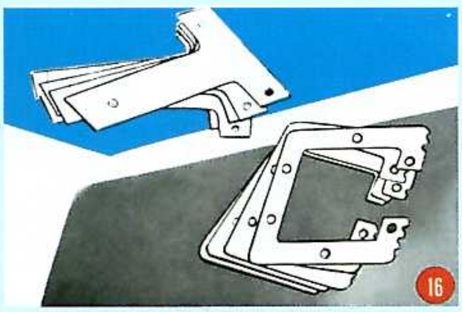
To eliminate this buzz, and to increase the solenoid holding power, Decco adds two copper loops, called shading coils, to the top of the "C" stack. Current is generated in each of these shading coils, and, most important, this generated current lags behind the applied current.



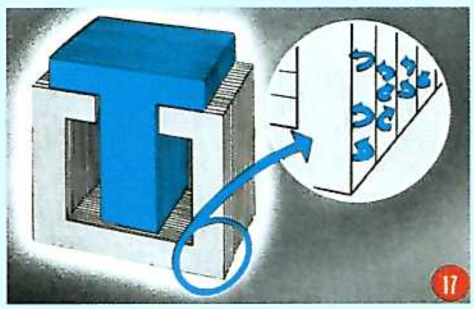
When the applied current is passing through zero, the shading coil current is at its maximum. This low shading coil current provides just enough magnetism to hold the plunger closed when applied current magnetism is at zero, thus eliminating the buzz.



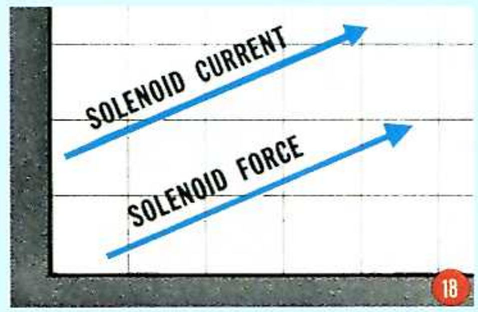
A.C. magnetic fluctuations also cause small stray currents, known as "eddy currents", to move in tiny circular paths within the "C" stack and plunger. Eddy currents consume power and cause a heat build-up which reduces solenoid force. We must minimize them.



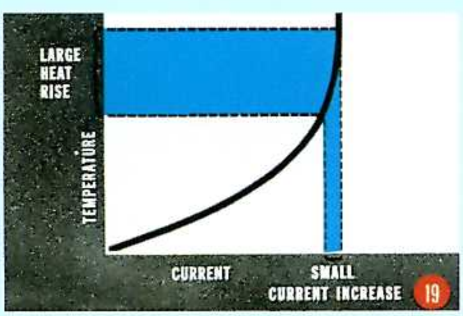
Decco makes the "C" stack and plunger of many thin sheets, or laminations, and coats each lamination with insulation. This contains the eddy currents within each lamination.



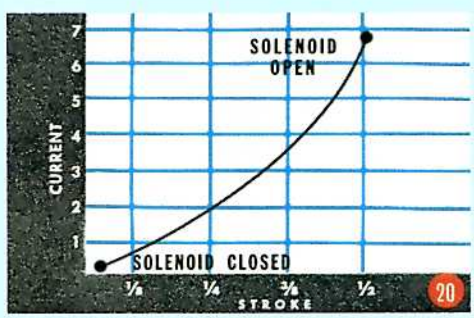
Magnetism can easily flow in its usual path around the coil, but the eddy currents cannot flow from one lamination to another. By containing the eddy currents within each lamination, (limiting their paths), we reduce heating and increase solenoid force.



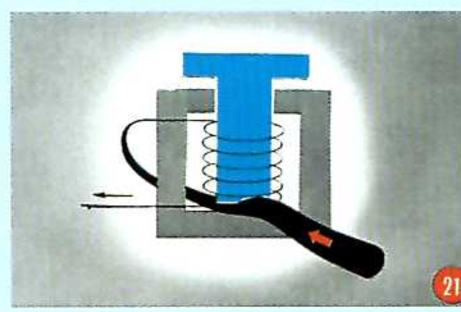
Here's another important fact about solenoid operation. Increased current in a solenoid coil produces increased magnetism which increases solenoid force. So ... why don't we rig up a deal to ram all the current we can into a solenoid?



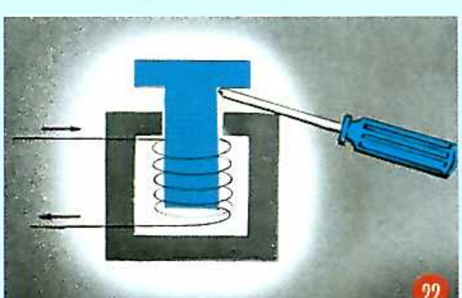
Because current generates heat, and generates it fast. If you double the current you increase the heat four fold. A small increase in current causes a great rise in temperature, which can burn out a coil.



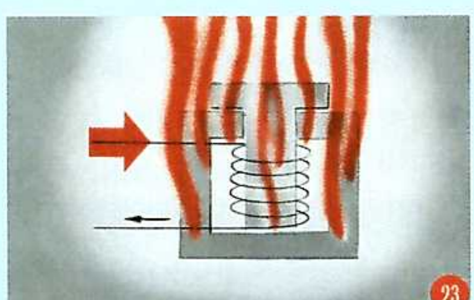
As a solenoid closes, the flow of current decreases. The peak INRUSH CURRENT in the coil when the solenoid is open is several times greater than the "solenoid closed" HOLDING CURRENT due to A.C. resistance (or IMPEDANCE) which increases as the solenoid closes.



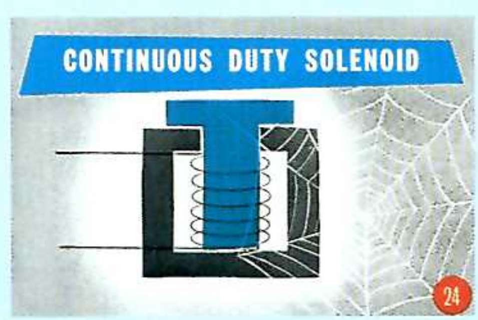
Here is an analogy to help you fix this situation in your mind. Visualize current flowing to the coil through a rubber tube. This tube runs under the solenoid plunger. As the solenoid closes, it pinches the tube, reducing the flow of current to the coil.



Remember – when a solenoid is open, it draws a high inrush current, which decreases as the solenoid closes. Now ... suppose we energize a solenoid, but mechanically block it open. The high inrush current will continue to flow in the coil.

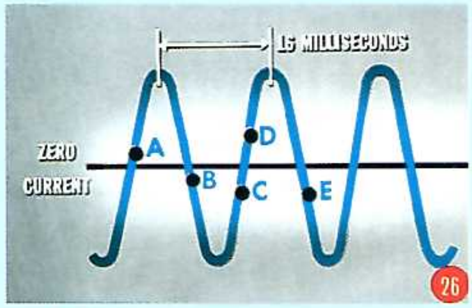


This high current will generate more heat than the solenoid can dissipate. The coil wire insulation burns, the bobbin melts, and the coil shorts out – all in a minute or two. Applying too heavy a load to a solenoid will hold the plunger open in the same way.

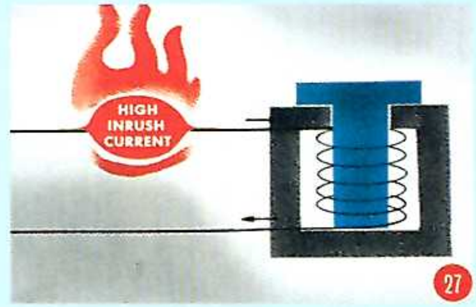


A CONTINUOUS DUTY SOLENOID is one that can be held energized indefinitely without overheating. The heat dissipating ability of this solenoid is great enough to get rid of all the heat generated by the coil's lower holding current.

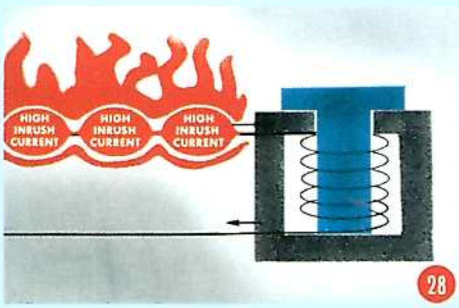
We can get a large force from a small solenoid (by increasing the current) only if the application permits a very short solenoid "ON time" and a long "OFF time". This INTERMITTENT DUTY SOLENOID must be de-energized before it gets hot enough to burn up the coil. It cannot be continuously energized.



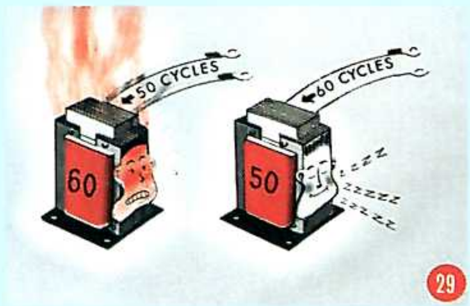
An A.C. solenoid should close in approximately 8 to 16 milliseconds. A solenoid energized at Point A should close at Point B, (about 8 milliseconds). When energized at Point C, the solenoid may not start until Point D, and finish until Point E, (about 8 milliseconds).



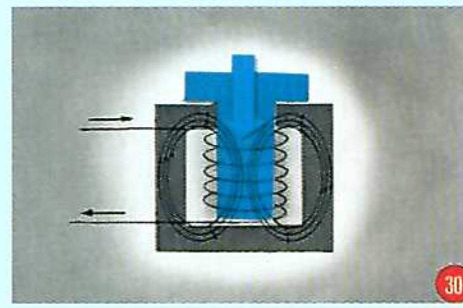
As a solenoid is cycled faster, its temperature rises and its force decreases. Each time a solenoid is cycled (or closed), it receives a high pulse of inrush current which generates heat in the coil. If these inrush pulses come fast enough…



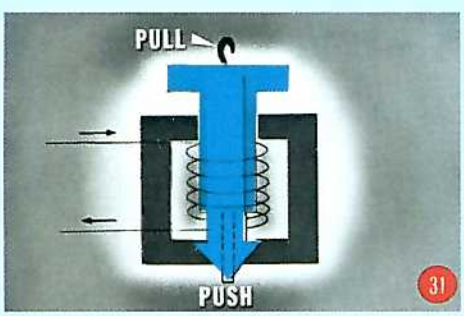
…heat builds up faster than the solenoid can dissipate it. As the coil heats up, resistance increases, current flow and magnetism are reduced. The solenoid loses power and becomes too weak to close. The coil receives a continuous inrush current, and it burns out.



99% of all U.S. power is 60 cycle frequency, and over 90% of all power outside the U.S. is either 50 or 60 cycle. A 60 cycle solenoid will overheat when operated on 50 cycles, and a 50 cycle solenoid will not produce rated force when operated on 60 cycles. Always use a coil designed for your specific power supply.



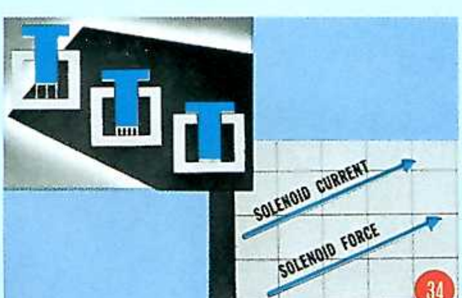
To summarize … a solenoid is simply a special electromagnet. Magnetism produced by the coil current draws the plunger into the coil, reducing the high resistance air gap, and allowing the magnetism to flow 100% though low resistance iron.



We can make a solenoid pull by hooking onto the top of the plunger, or push from the bottom of the plunger.

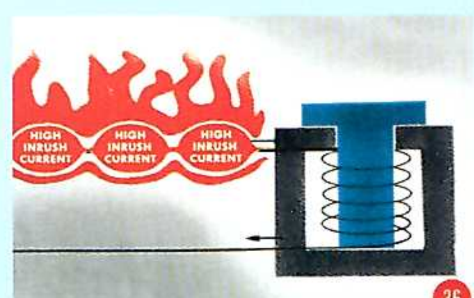
Decco's copper shading coils keep a solenoid quiet by supplementing A.C. current fluctuations.

Decco's insulated and laminated "C" stack and plunger reduce eddy currents and keep a solenoid cool.



Solenoid force increases as the plunger closes – due to reduced air gap at the bottom of the plunger. Solenoid force also increases with an increase in coil current.

When a solenoid is open, the inrush current is high, but drops as the solenoid closes.



And finally – the faster you cycle a solenoid, the hotter it gets. If cycled too fast, it will overheat and burn out.