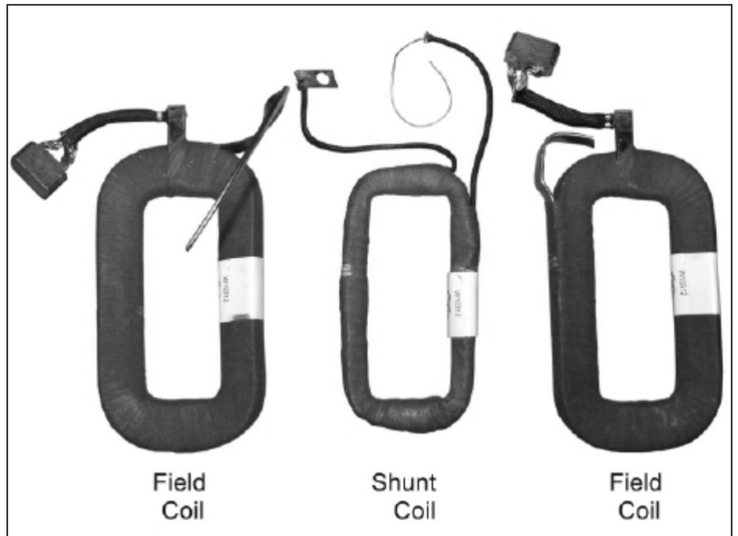


Figure 1—Two series-coils and a shunt-coil.

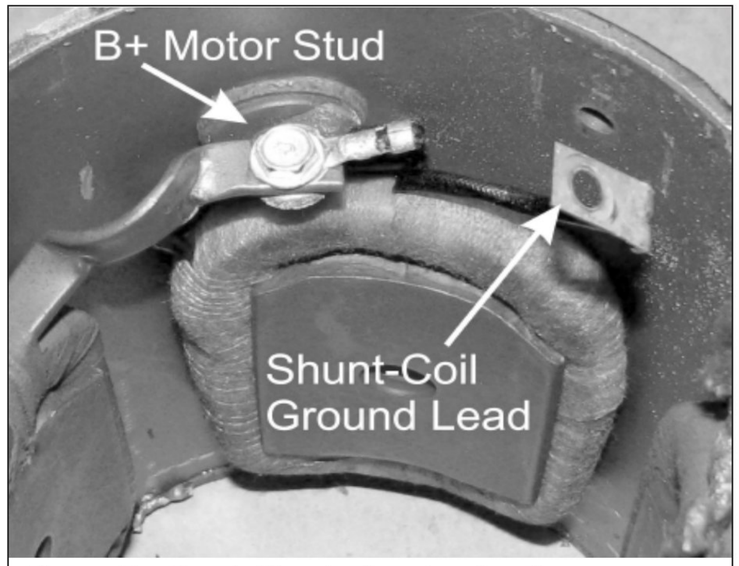


Figure 5—Prestolite starter shunt coil.

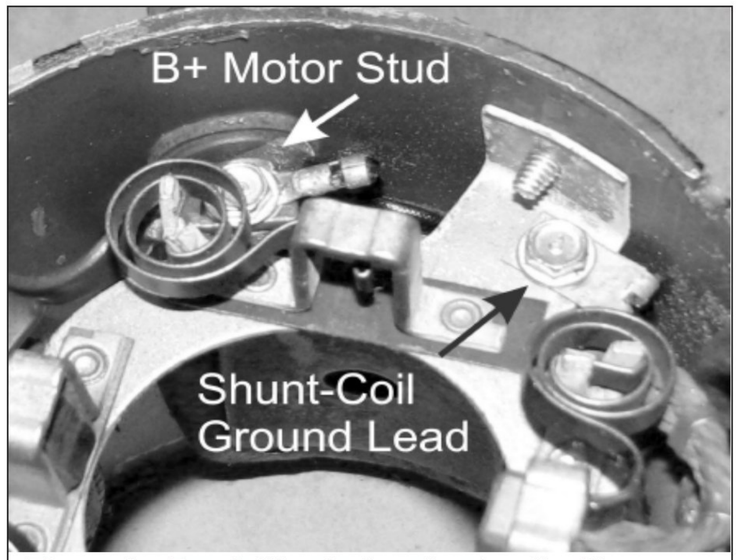


Figure 6—Prestolite starter shunt-coil with brush plate installed.

Starter shunt field coils: Clearing up confusion

COLUMN BY WES GRUENINGER SR. AND BOB THOMAS

A shunt coil (see Figure 1) is simply a field coil connected directly to the battery in parallel with the armature, as opposed to being connected in series with the armature, as most starter field coils are. Shunt coils have been used in many different starters and sometimes cause confusion or misunderstanding for rebuilders. Why is the shunt coil there, what does it really do and how does it work?

The general conception is that a shunt coil will slow down a starter while providing more torque. While true in a sense, it is not really the whole truth. In actuality, a shunt coil does limit the speed of the armature, and it often provides some additional torque. But it also allows the starter to crank the engine with equal or better torque using less amperage. We will explain how a simple shunt coil can do all this, but first let's look at the characteristics of both series-wound and shunt-wound configuration DC motors:

Series-wound DC motor (Figure 2):

- It has high starting torque to handle high mechanical loads.
- As the load decreases, amperage draw decreases.
- If the load is suddenly removed, armature speed rapidly increases.
- Armature speed under no-load conditions can exceed safe limits.

Shunt-wound DC motor (Figure 3):

- It has low starting torque.
- Torque increases with armature speed.
- Armature "motors" at a constant speed under no load.
- It provides torque to match the load once constant speed is reached.

As you can see, the series-wound motor is the better choice for a starter. It provides maximum torque at start-up when you need it most to get past that first compression stroke. However, that benefit comes with a drawback—excessive armature speed if the load is suddenly removed. Each time the starter is used, the moment the engine starts, the load is instantly lifted, and the armature is overrun until the starter has had time to disengage.

This is where a starter with only series coils can cause problems. When you see an armature that has been spun so fast that the wires are thrown out of their slots, it is almost always a series wound starter. A single shunt coil can limit over-run without sacrificing any of the series coil benefits. That is why you often find one or two shunt coils used in conjunction with series coils. Delco, Prestolite, Ford and Chrysler have all used this configuration in various cranking motors over the last 60 years. Those starters combined the best characteristics of both designs.

To understand how the shunt coil works, you need to know about counter electromotive force.

Counter electromotive force

Electromotive force, or EMF, is actually just another name for voltage—the pressure behind the flow of current. In a starting circuit, the battery is the source of all EMF. Counter electromotive force or CEMF, is generated in the armature whenever the windings cut through magnetic lines of force—whether it is free spinning on your bench or cranking an engine. CEMF is always opposite polarity to the normal flow of current through a starter. In other words, it opposes the flow of current that is forcing the armature to turn in the first place. The amount of CEMF is determined by the speed at which the armature cuts through the magnetic lines of force and the strength of those lines.

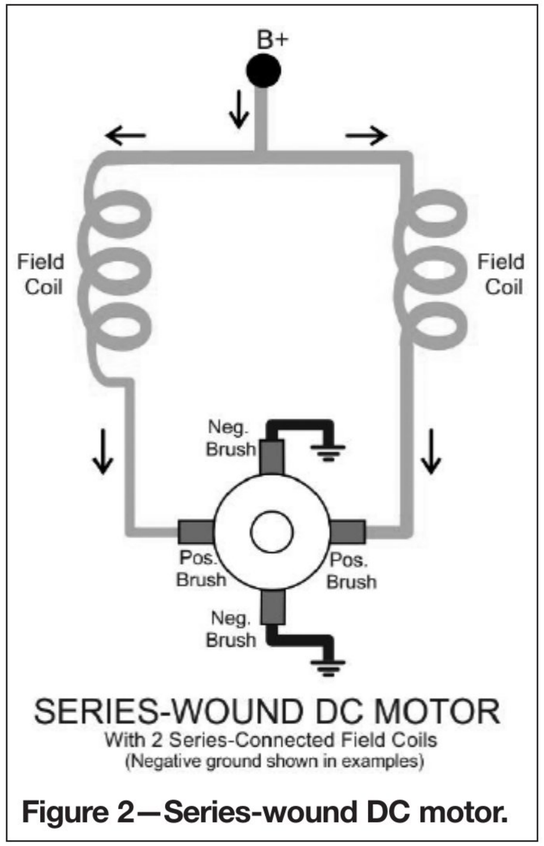


Figure 2—Series-wound DC motor.

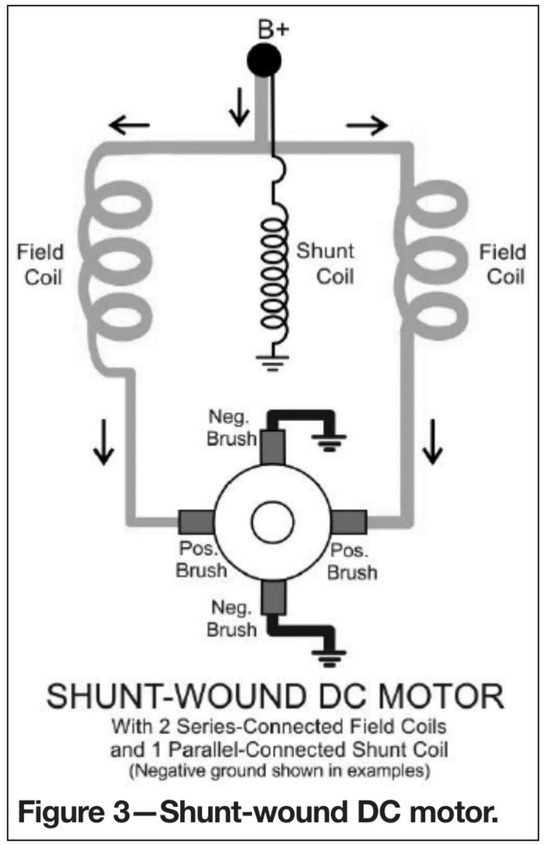


Figure 3—Shunt-wound DC motor.

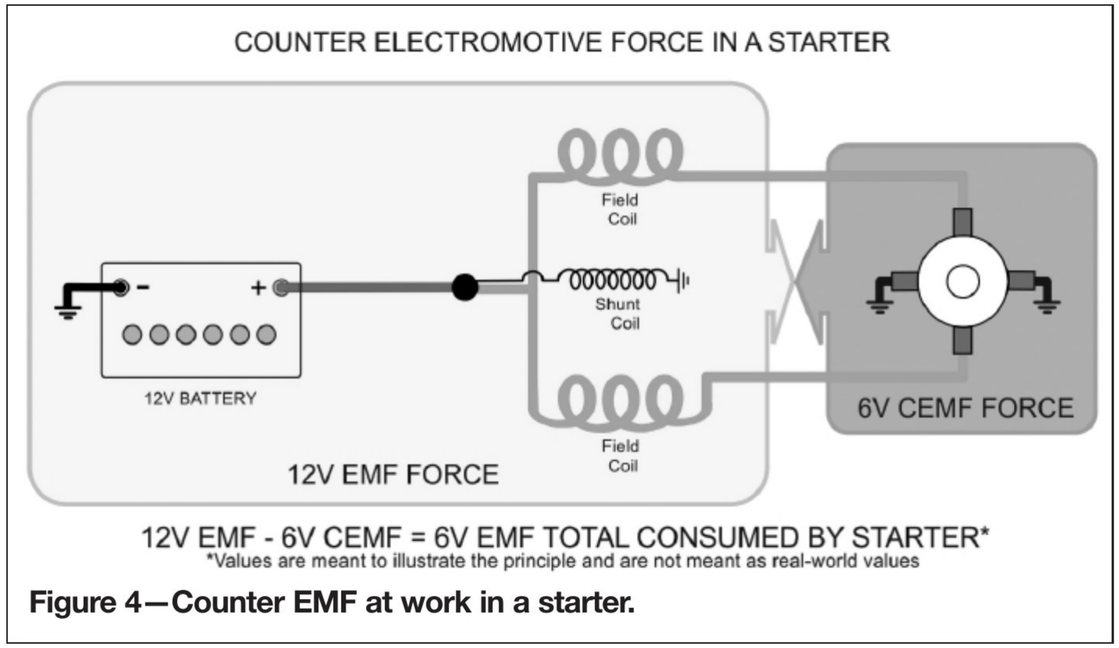


Figure 4—Counter EMF at work in a starter.

If you have ever checked amperage draw when free-spin testing a starter, you have seen and measured the effects of CEMF. On start-up, you will see high amperage draw which quickly drops as the speed of the armature increases. The amperage drops because CEMF pushes back against the battery voltage coming into the motor. The higher the CEMF, the lower the EMF (or voltage) that is being consumed by the starter. Following Ohm's Law, lower voltage means lower amperage, because the actual resistance in the starter has not changed.

CEMF in a series-wound starter

In a starter with field coils in series with the armature, the amperage is high on start-up, but armature speed is very low. That means that little CEMF is being generated at start-up. Then, as the armature speed increases, CEMF will increase. This gain in CEMF causes amperage to drop, as explained above. Because current flows through the field coils and the armature in series, less current is now also flowing through the field coils. In turn, this reduces the strength of the magnetic lines of force. This limits the amount of CEMF that can be produced in a series-wound starter armature.

This type of starter will reach its lowest amperage draw in a free spin test the moment its maximum armature speed is reached. This is also when maximum CEMF is being generated. However, if the load is suddenly removed, this type of starter can exceed its maximum speed. This happens because the torque does not "go away" the instant the load is removed. The torque is still there when the engine starts. By the time magnetic fields have had time to react, the unloaded starter has already been given an big extra push.

CEMF in a series-wound starter with a shunt coil

A shunt coil utilizes many more turns of smaller wire than a series coil. It has a high resistance and has almost minimal effect on overall amperage draw of the starter. When a shunt coil is present, the current flowing through it remains constant. That is because it is connected directly to the battery and is not affected by CEMF in the armature. This constant high magnetic strength in the shunt magnetic pole greatly increases the CEMF in the armature. This higher CEMF has two effects. First, it limits armature speed much better without giving up any torque performance on start-up, and at the same time, it reduces the total amperage draw of the starter.

You may wonder how this little shunt coil can produce the same magnetic force as each of the series coils. Magnetic strength is determined by the amount of amperage flow and the number of turns in the coil. The current flow through the shunt coil is indeed very low. We have all measured it when testing shunt coils. But while a series coil may have only a half dozen turns of very heavy wire, the shunt coil may have 50 to 100 turns of small wire. The shunt coil has been wound with enough turns to produce the same magnetic strength as the series coils, so there is no loss of torque. Because the current flow remains constant through the shunt coil throughout the starting process, a starter with a shunt coil will actually lose less torque as armature speed increases. During cranking, the shunt coil gives the

starter more torque than it would have had without it.

So, how can a shunt coil reduce amperage draw, too? On start-up, the shunt-wound starter puts less of an amperage load on the battery than a standard series wound starter. Then, as the speed of the armature increases, it generates greater CEMF, causing the amperage to drop significantly. The overall affect is lower amperage draw throughout the cranking sequence. You can measure the effect of the shunt coil on amperage by bench testing the same starter with the shunt coil connected and not connected. You will also be able to hear the starter "motor" at a safe and constant speed with the shunt coil connected.

Shunt coil polarity

Rebuilders may occasionally find themselves replacing a shunt coil, unsure of which coil lead is positive and which is negative. The polarity of the shunt coil must be opposite the coils next to it. If you cannot tell which way the wire is wound inside the wrapping, you can use a compass to check the polarity by passing current through the shunt coil. If you happen to hook it up backwards, you will know when you free-spin test the starter. The correct polarity will give you a very noticeably smooth and constant armature speed, and amperage draw will be low. When a shunt coil is hooked up wrong, the starter will "motor" very fast and draw significantly more amperage.

Courtesy of the Electrical Rebuilder's Association. This Technical Document (SS201112A) along with other technical and membership information, may be accessed at electricalrebuilders.org.

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