

Lucas M50 Starters with Double-Contact Solenoids

Farmers are an independent lot. They can fix anything and get by with next to nothing. As a result, there is a lot of vintage equipment out there still being used.



Figure 1—Lucas M50 Starter

Many older machines have the (in)famous Lucas M50 double-contact type starters. Some examples are Lester # 17646, 17072, 17071, and 17649.

Every so often, as I rebuild one, I have to replace a burned field coil (see Figure 2), and it is always the same one of the four. Often, the solenoid coils are burned inside as well. Why?

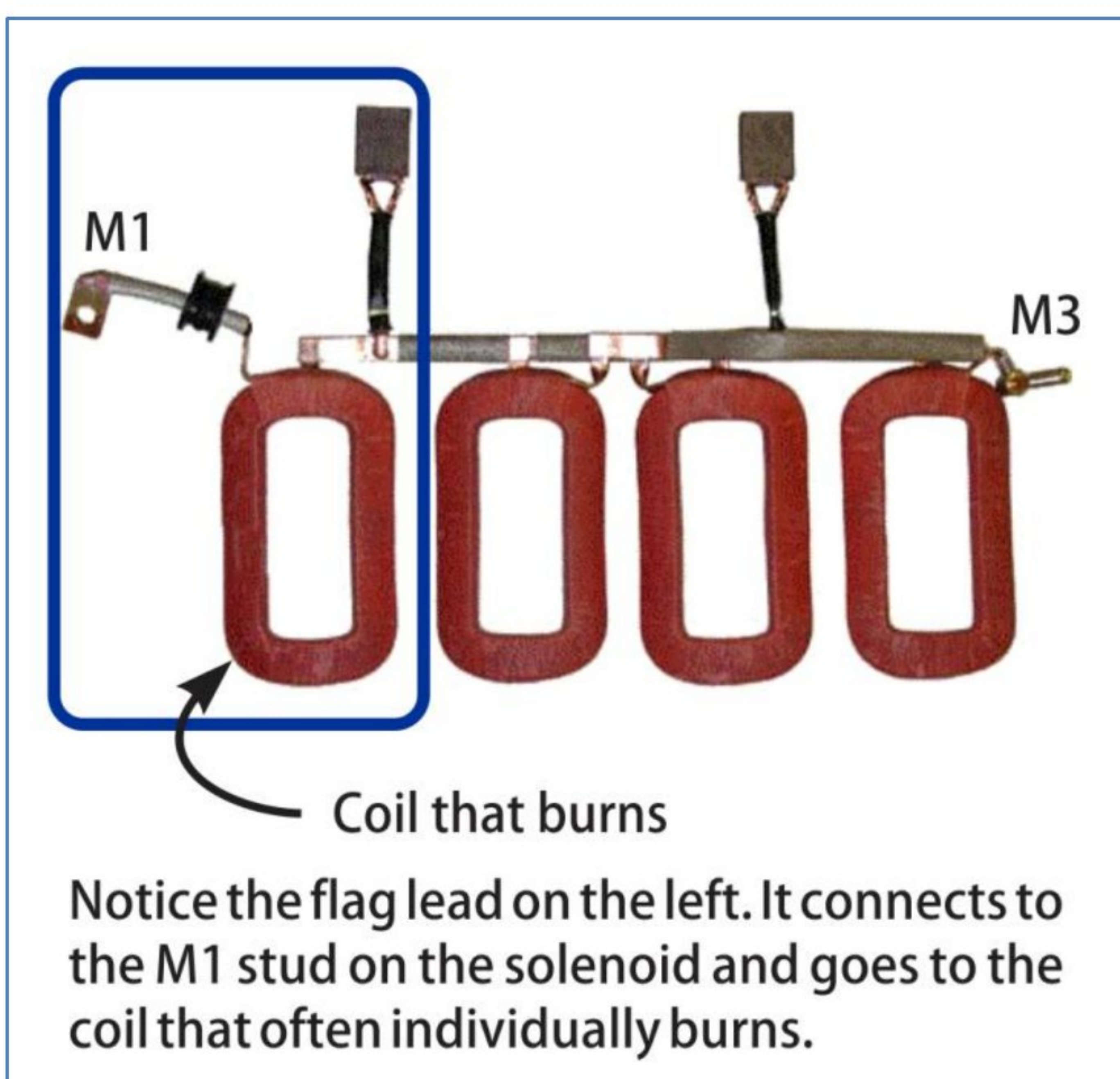


Figure 2—M50 Field Coils

I've found that it's because only one set of contacts ($B+$ to $M1$) closes. It might be that the second contact set ($B+$ to $M3$) is burned/fouled, or it may be that the pinion clearance is too tight, preventing the linkage from allowing the $M3$ contacts to close.

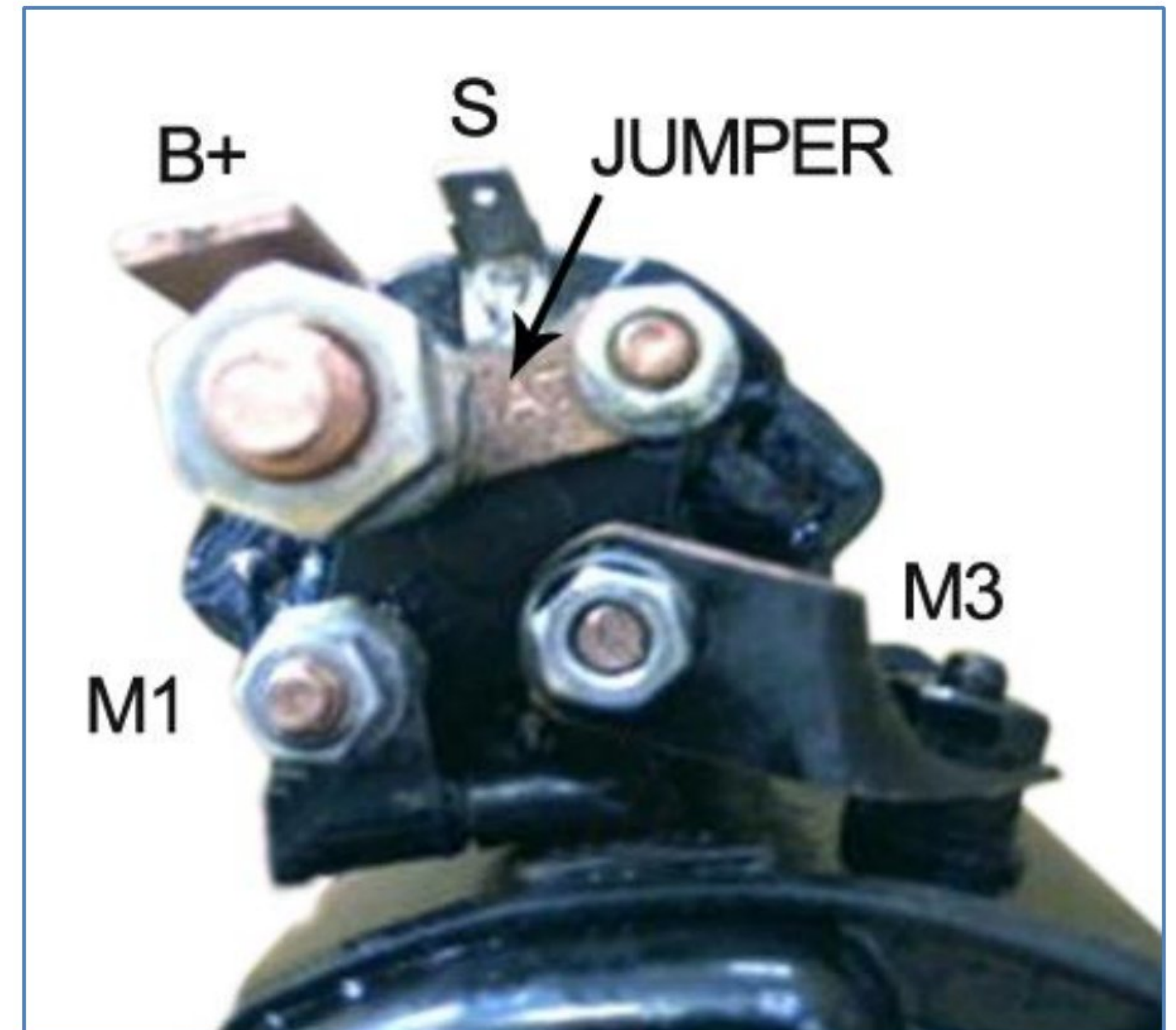


Figure 3—Solenoid Terminals

Thus, the current flows through only the first set of contacts, and therefore, flows through only the one shunt coil. The starter then cranks only very slowly. The temptation is to keep trying until the tractor starts “just one more time”.

Also, the high current pull-in coil of the solenoid is not cancelled, because the contacts it is connected to don't close, causing the solenoid to overheat. (More on this later) This is also hard on the ignition switch.

But why use the double-contact solenoid design (also called two-stage) in the first place?

The way I figure it, some time ago, some engineers were looking at chewed up starter drive gears and ring gears and decided that something had to be done about that.

Did it have to do with the fact that in the instant when the solenoid contacts closed, the armature started turning at the same time, whether or not the drive was already meshed?

They probably started to make changes to the linkage, introducing things like mechanical hysteresis, various springs offsetting each other, adjustable clearance, different spline angles on the armature, interrupted linkage, and other things engineers like to write calculus equations about.

Then they came up with this wonder: “Soft Start”.

If the solenoid could throw out the drive and engage only one of the field coils, then the armature would accelerate only slowly. In the case where, at first attempt, the drive teeth didn't mesh with the ring gear (called tooth abutment), then the drive would turn only slowly while the internal spring in the plunger would hold pressure on the drive. Once the drive engaged fully, it would allow the other set of contacts to connect the rest of the field coils for full cranking power.

Take notice of the plunger (see *Figure 4*) – it is unique to the double-contact solenoid in that it has a hole in the bottom of it. This is so that it will not push on the second set of moveable contacts during tooth abutment.



Figure 4—M50 Plunger Assembly

This soft-start process would prevent the armature from being able to turn too fast before full engagement, thus preventing the gears from skipping and grinding.

That's how I figure they came up with this Lucas M50 soft-start set up with double contacts and double field-coil connections.

But this design has its weaknesses, too.

If the second set of contacts were fouled, or if the pinion clearance were set too tight to allow them to close, then only the single coil would get power. On the other hand, if the pinion clearance were too slack, then the gears would grind anyway.

Picture the farmer out there on a cold morning, spraying ether into the air intake, all the while torturing his starter. Then imagine an old battery with greenish terminals and snaggly jumper cables running up somewhere under the hood of his pickup—until finally, the phone rings at your shop...

Educate the Customer

Advise the farmer to change his ignition switch and replace all bad connections, grounds, and wiring. Also, tell him that the pad area onto which the starter mounts must be clean and free of rust. Although the starter has a ground bolt at the back, many machines have no ground strap. Make sure he has a good, fully charged battery. Low voltage to the S-terminal causes chattering, which can burn out the contacts.

In addition, low voltage to the starter causes it to draw excessive current, which also burns out the contacts prematurely. Since these starters are typically found on older machines, you can expect lots of voltage-drop problems, and those can be difficult to find if the farmer doesn't know how to do voltage-drop testing. There is a great article by Wes Grueninger and Bob Thomas on voltage-drop testing on the ERA website in the Technical Articles Library¹. You could even print it up and give a copy to the farmer.

Service the Starter

You can use a coil from another set (you know, make one good set out of two bad sets), first making sure it is wound in the same direction. Some suppliers may sell that one coil separately.

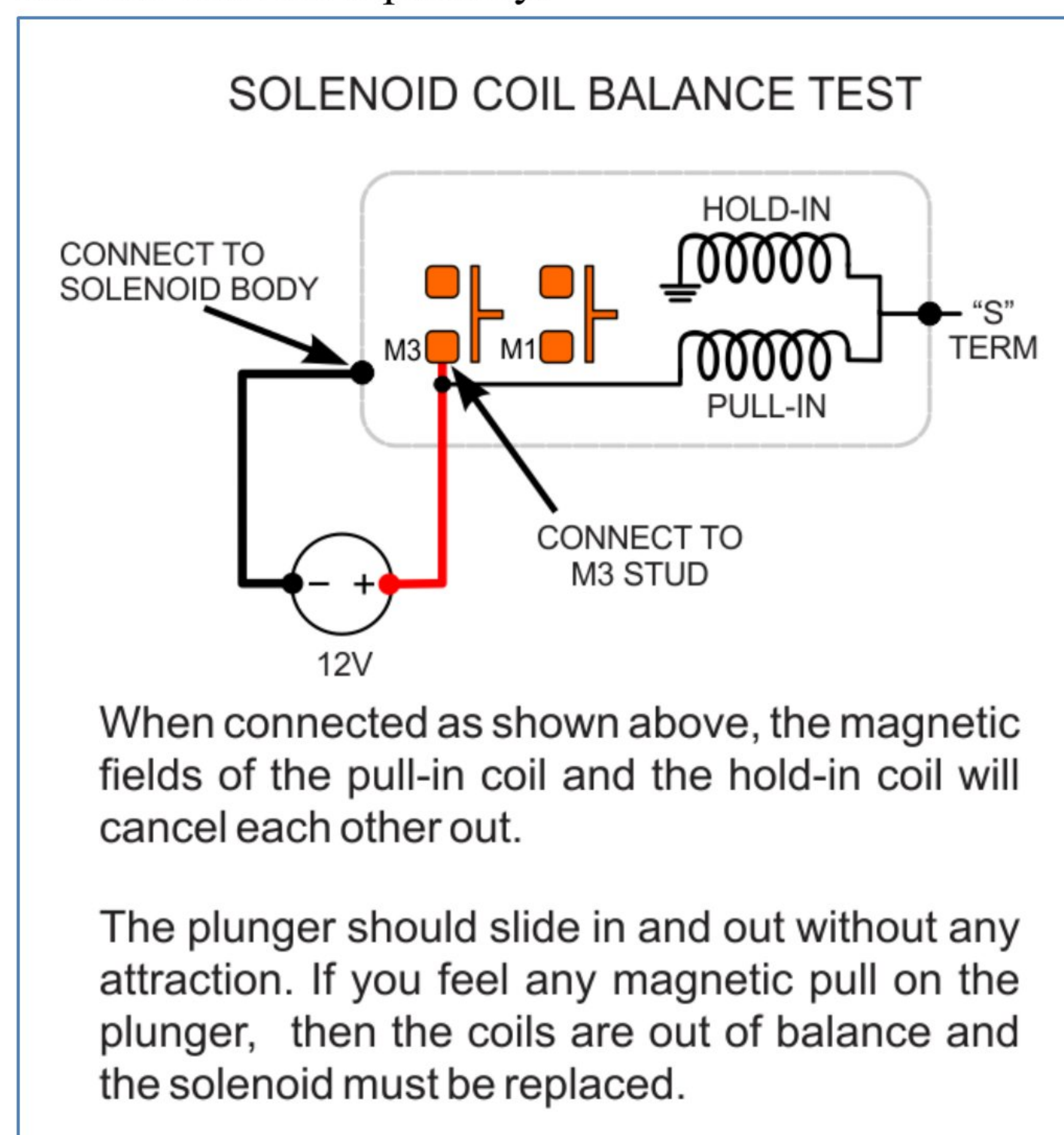


Figure 5—Solenoid Coil Balance Test

The solenoid coils have to be checked for balance. Put 12v to M3, ground the case and slide a plunger in to see if it is magnetically attracted (see *Figure 5*). It shouldn't be. If it passes that test, then you should still



visually inspect the coils to make sure that they are not overheated. If they are, you may want to just replace the whole thing. To inspect the coils, drill a small very shallow hole in the side of the solenoid case. Inspect the coils, and then fill the hole with a dab of sealant.

Rebuild the starter as required.

Adjusting the Pinion Clearance

First, let's check the pinion clearance (see *Figure 6*). In an old ACE bulletin from January 1998 the specification calls for 0.015"– 0.025" pinion clearance. To measure this, ground the starter, apply 6V (to avoid overheating the solenoid coils) to the small S-spade terminal but not to the B+ copper bolt, and push the drive back to remove any slack. Because armatures

can have a bit of end-play, make sure the armature is slid all the way forward as well. This distance between the drive gear and the stop collar is *pinion clearance*. Pinion clearance can be adjusted by rotating the shift lever pivot bolt, which has a cam action supporting the shift lever. First loosen the back-nut, make your adjustment, and then retighten the back-nut to keep its position.

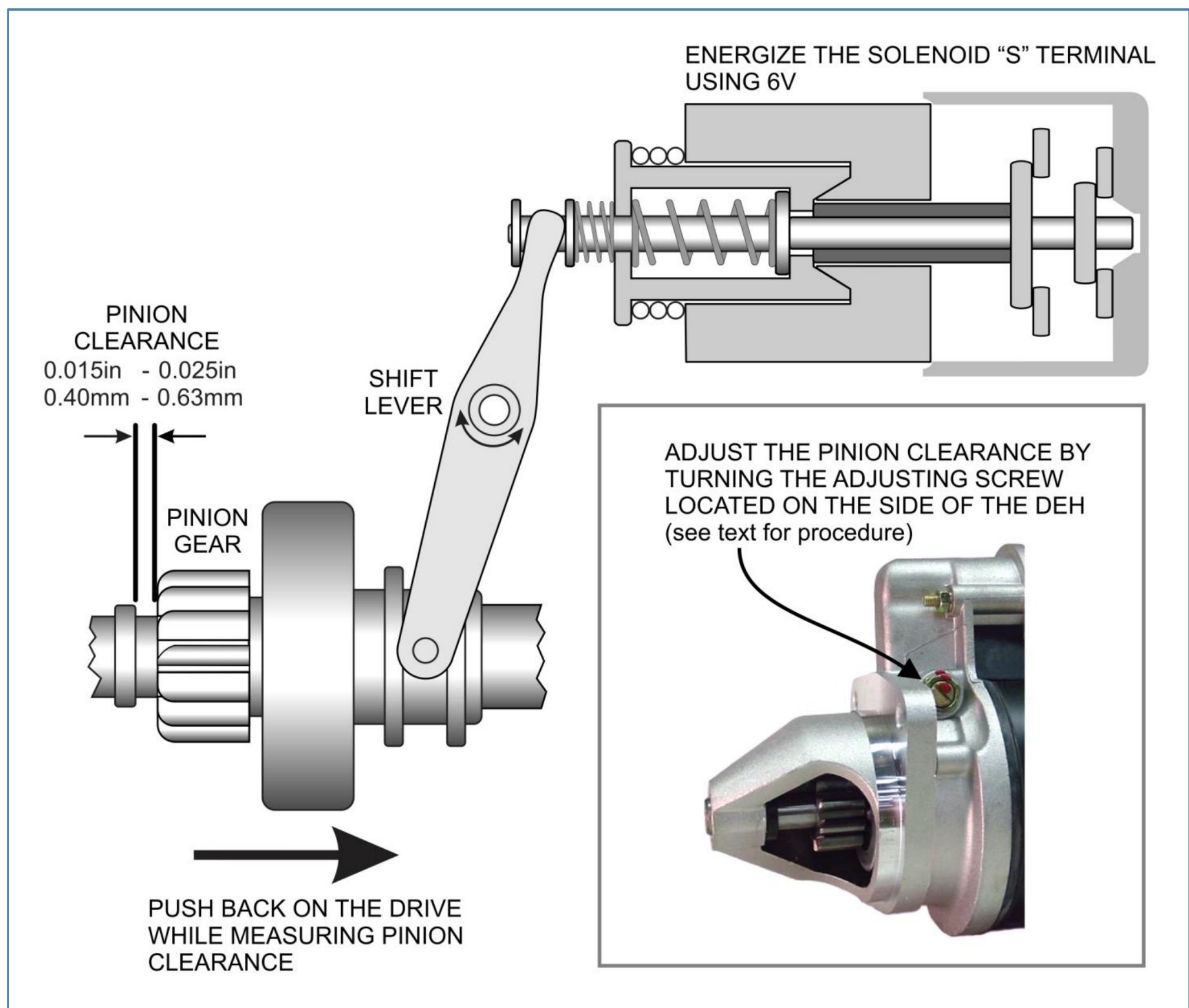


Figure 6—Adjusting Pinion Clearance



Understanding the Starter

Are you sitting down?

Here goes:

First we start with a wiring diagram (see *Figure 7*).

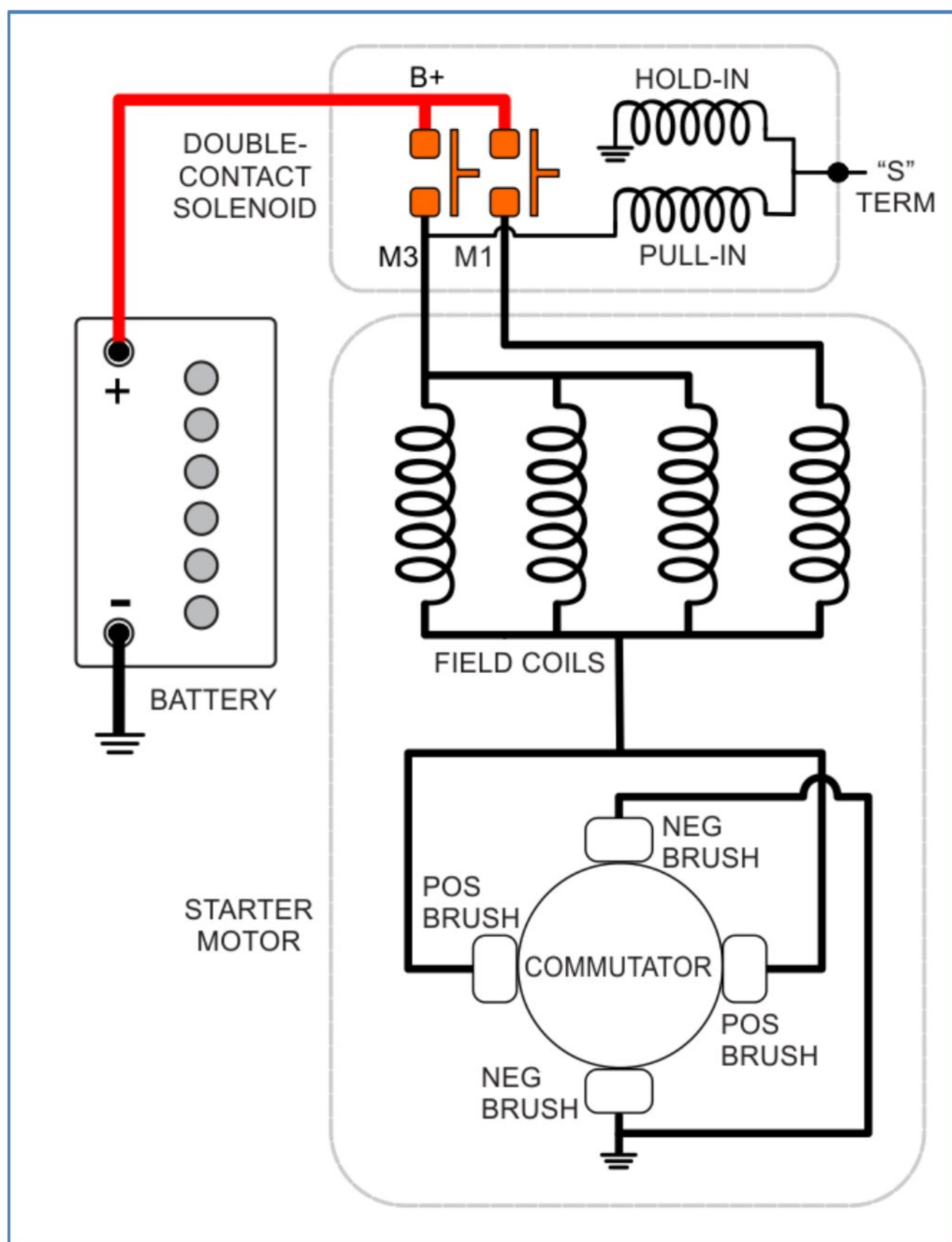


Figure 7—M50 Circuit Diagram

Notice that all the field coils are in parallel to each other (4 shunt coils) except for the one which is connected to an independent set of contacts (*M1*). Refer again to *Figure 2* and *Figure 3*.

Installed on the machine, the power on *B+* of the starter is present all the time. Power is applied to the *S*-terminal via the start button/ignition switch, and current flows through both solenoid coils—a total of 92A on one I tested. The hold-in coil is connected directly to ground. It is active the whole time the *S*-circuit is powered up. The pull-in coil is grounded through the fields and the armature at the “motor” stud of the 3 coils (This is that second set I discussed earlier, *M3* in *Figure 3*). As soon as the *M3* contacts are closed, the pull-in coil will have 12V on both ends and no current will flow through it (see *Figure 10*). This prevents the pull-in coil from overheating and also lowers the current flowing through the ignition

switch and other components of the *S*-circuit, down to about 16A. The pull-in coil does most of the work of pulling the plunger in and is wound with thicker wire than the hold-in coil. Even though it has the same number of turns as the hold-in coil, it draws a lot more current—about 76A by itself in my test unit. It works together with the hold-in coil and actually contributes to the soft-start effort to clear tooth abutment. I’ve even seen a number of starters by other manufacturers where the soft-start feature depends on the pull-in coil current.

Now let's look at this in slow motion...

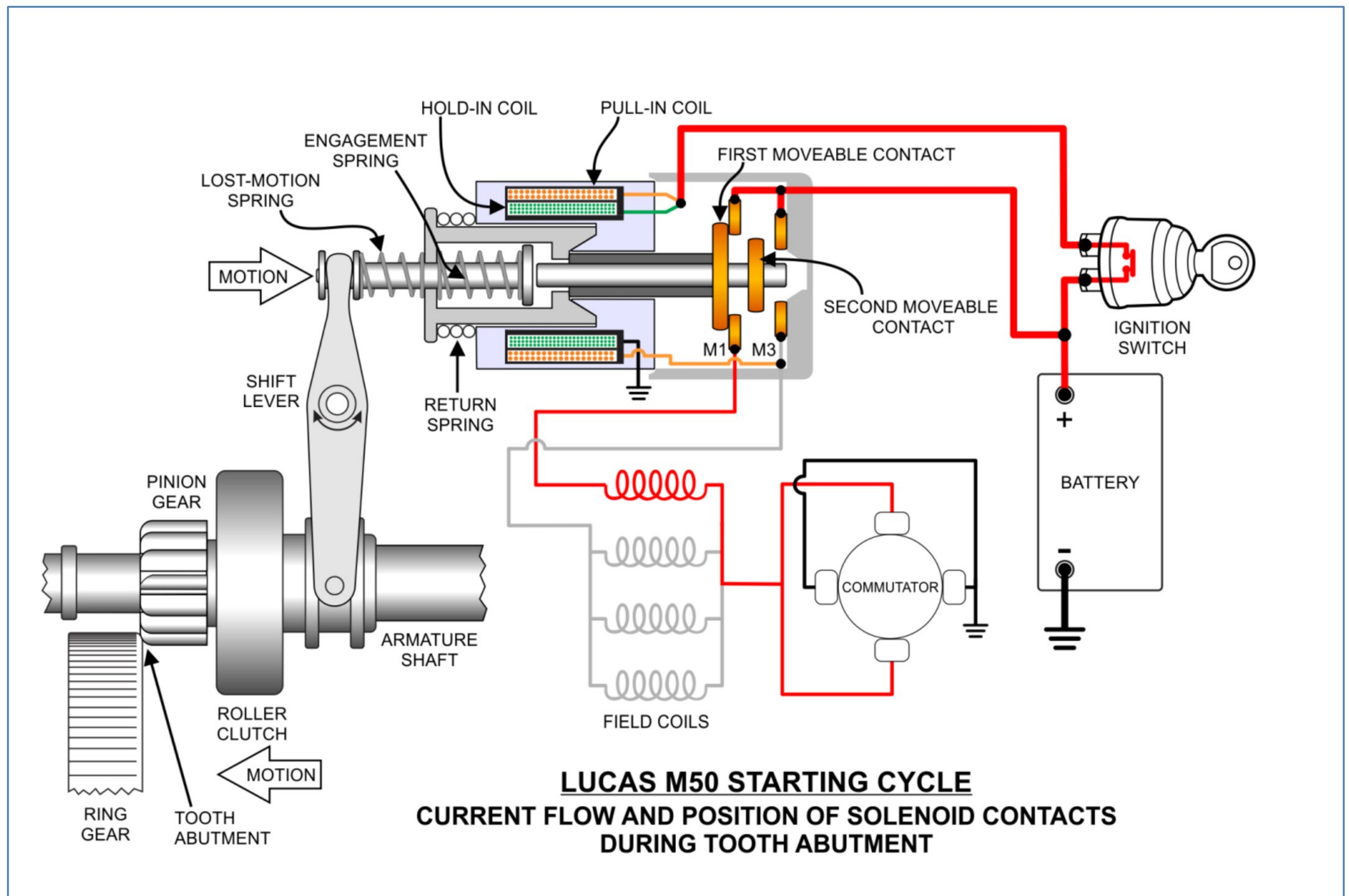


Figure 8—Starter Drive and Ring Gear Tooth Abutment

Step 1: As the solenoid plunger starts to pull in, the drive starts to engage the ring gear. Almost immediately the M1 contacts close. This means that current flows through the single shunt coil. Together with the pull-in coil current through M3, we now have enough current to make the armature rotate slowly. If it should happen that we get tooth abutment at first (see Figure 8), then the linkage will not allow the M3 contacts to close yet.

(Exception: if your pinion clearance is excessive, it may allow the M3 contacts to close prematurely. That can cause milling of the gears.) But, during the time that the plunger is moving, the S-circuit is carrying 92A. All this current is coming from the ignition switch!! As soon as the M3 contacts close, that current drops to 16A.

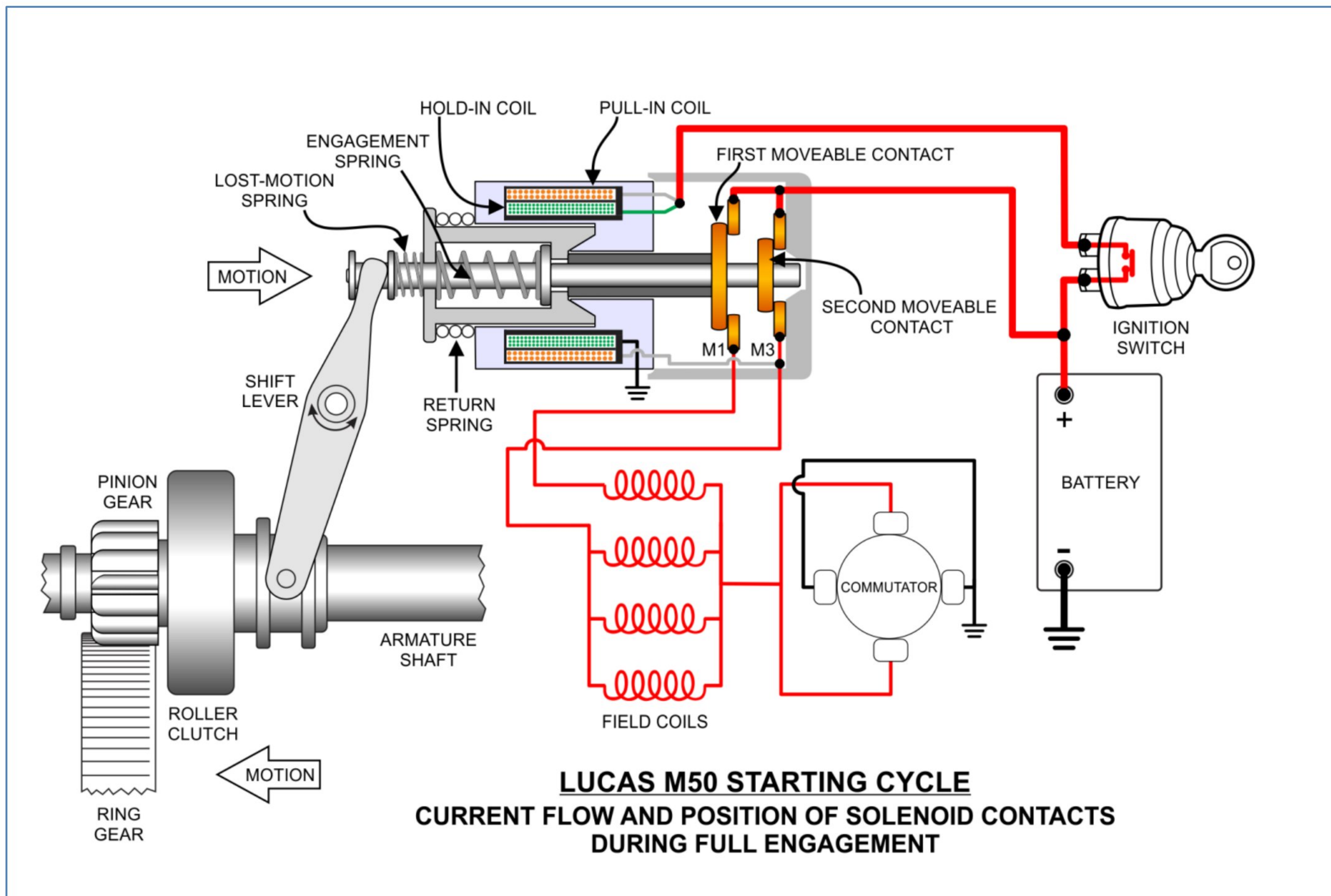


Figure 9—Starter Drive is Fully Engaged

Step 2: As the armature rotates slowly, it clears the abutment position and engages the ring gear fully (see Figure 9). The linkage then allows the M3 contacts to close, giving full power to the remaining 3 field coils, allowing the starter to properly crank the engine.

Step 3: In that small fraction of a second when the farmer quits cranking the engine, but before the solenoid contacts have time to release, there will be a current path from the power still available at the M3 stud, up to the now-released S-terminal, then through the hold-in coil to ground (see Figure 10).

Two things happen in that fraction of a second:

1. The current in the pull-in coil is reversed in direction, reversing its magnetic pull.
2. Current flows in series through the pull-in coil and the hold-in coil. Because of this, they both have the same amount of current—on my unit, about 13A. Remember Kirchhoff?² Current in a series circuit is the same at all points.

Since both coils have the same number of turns and the same amount of current, but opposite magnetic polarity, the net magnetic pull is zero. This allows the various springs in the linkage to open the contacts and return the plunger and the drive.

As an aside, notice that the pull-in coil is connected to M3, not to the motor stud of the single coil (M1). This means that if the M3 contacts don't close, you will have high current **continuously**, instead of just momentarily. According to my test unit, that's about 92A through the S-switch the whole time the farmer is tormenting his starter. This is one reason the solenoid coils get burned. Could this also burn out his ignition switch contacts? I've heard of that happening...

In some machines, they have an extra relay to protect the ignition switch and also improve the available voltage to the solenoid. This relay can be retrofitted as well. See the article on the ERA website in the Technical Article Library called *Solving Problems Using Relays - or - Four Handy Uses for Bosch Relays*

by Wes Grueninger & Bob Thomas—refer to *Problem Fix #1*.

To reiterate—the **single burned field coil is a result of the second set of contacts not closing**. That might be due to incorrect pinion clearance or worn/dirty contacts.

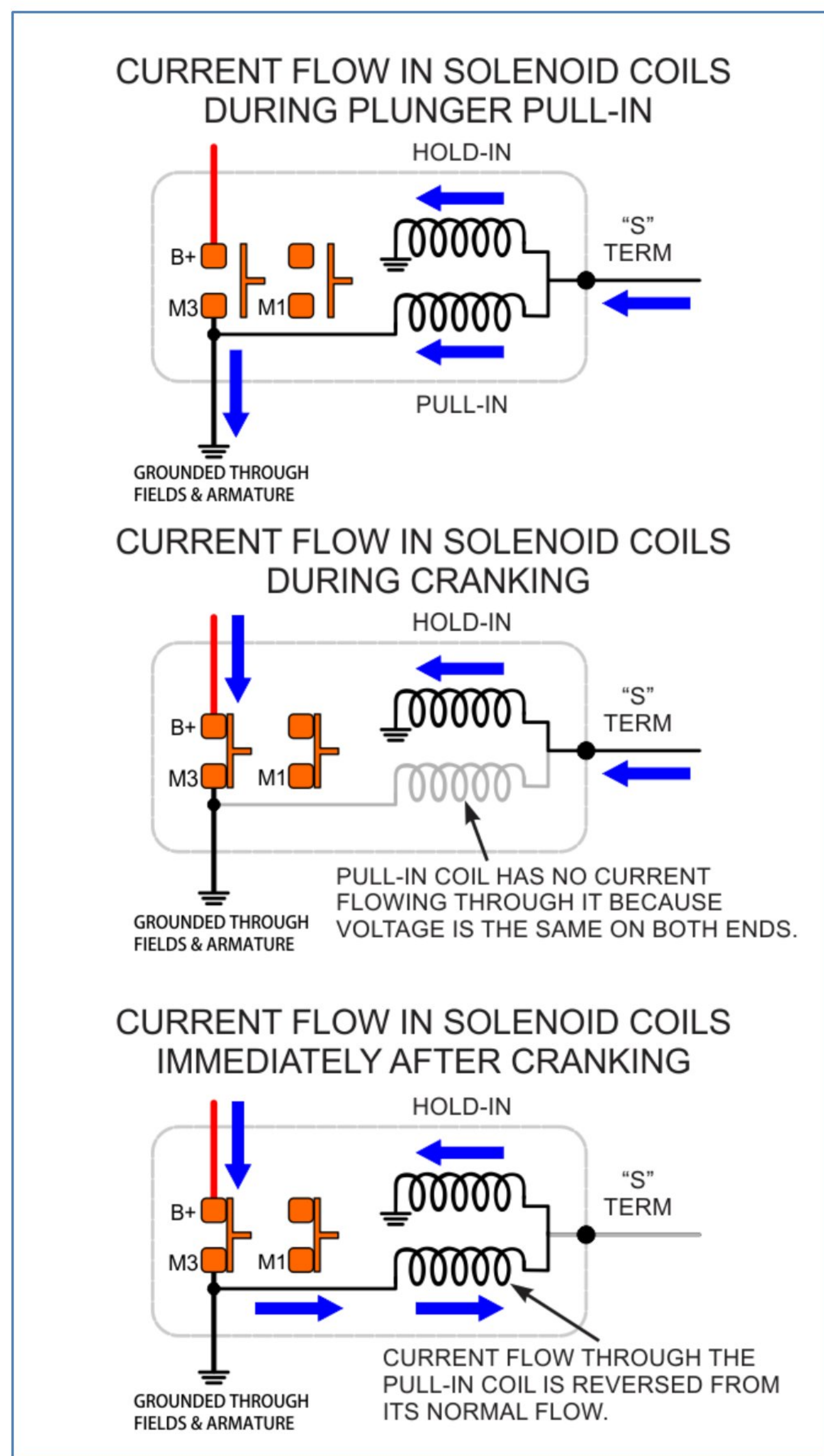


Figure 10—Current Flow in Solenoid Coils

Understanding Contact Voltage-Drop

Contact voltage-drop is a measure of how well the contacts conduct electricity when they close.

This is affected by the actual contact area, the contact pressure, and the composition/purity of the contacts, among other things.

On a free-run test, I usually see healthy contact voltages under 0.1V. When torque-loading the starter, around 0.3V is acceptable because of the higher current.

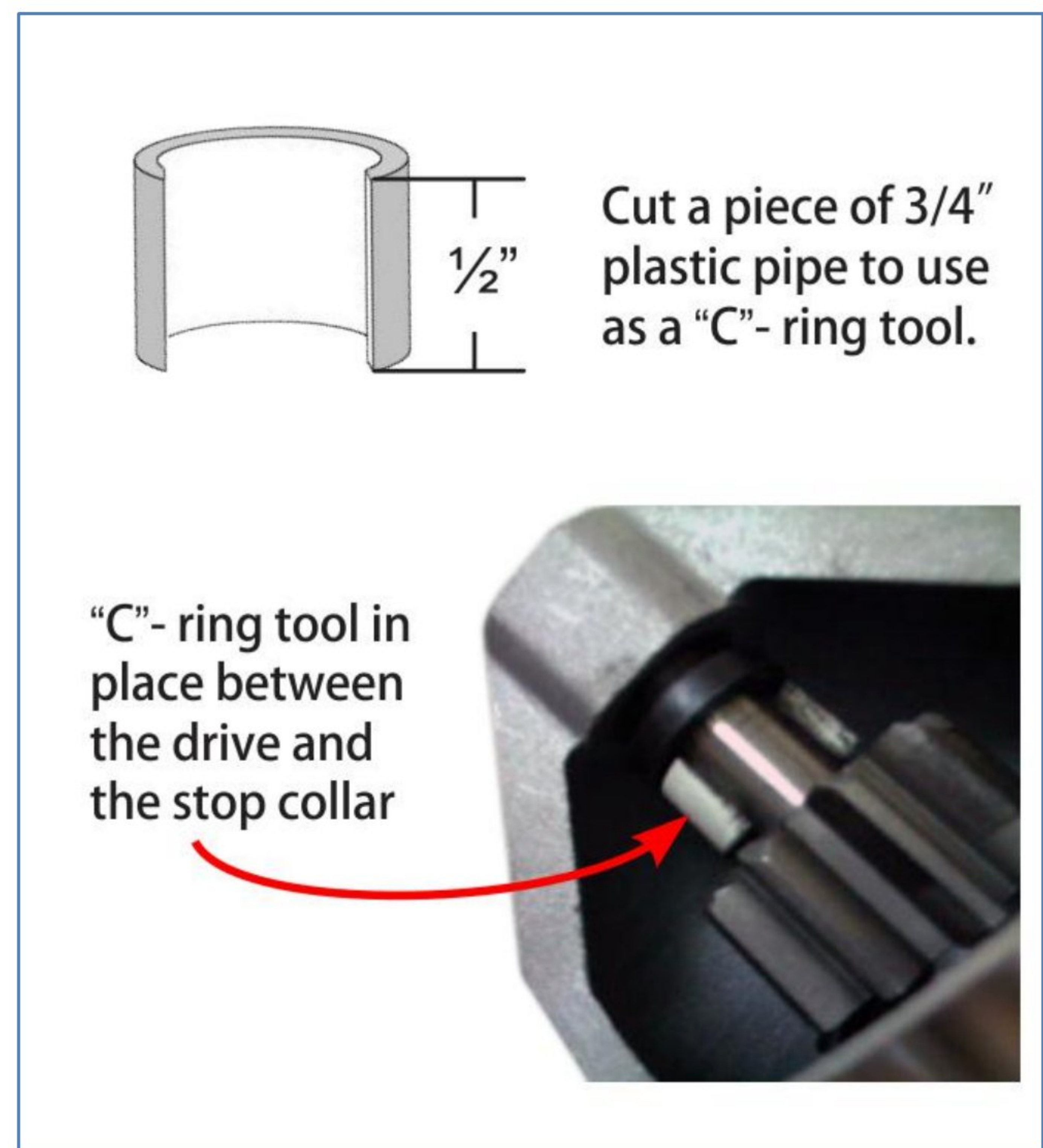


Figure 11—Using a "C"-ring tool

Verifying the Contact Closure Sequence

If we could block the drive back and yet still free-spin the starter, then we could determine if the second set of contacts stays open during abutment. I use a piece of 3/4" plastic pipe that I cut to a length of 1/2", which is just a little more than the width of engagement (see Figure 11). Cut a slice of 1/3 out of it, so it forms a "C"-shape. Snap this over the armature shaft in front of the drive. This will simulate the abutment condition.

Three Contact Voltage-Drop Tests With the "C"-ring Tool In Place

1. Put a voltmeter across the B+ and M3 terminals to measure the contact voltage-drop. Apply 12v to the B+ and S-terminal and do a free-run test.

You might see somewhere around 1.5V from B+ to M3. This actually indicates that the M3 contacts are open. (Remember there are parallel circuits involved.)

2. Now put your voltmeter between *B+* and *M1* and free-run the starter again. The meter should read less than 0.1 volt, indicating that the *M1* contact is closed and in good condition.
3. Lastly, remove the “C”-ring tool, put your voltmeter back on *B+* to *M3* again, and free-run the starter. This time the starter will accelerate a bit faster, and the voltage should be less than 0.1 volts, indicating that now the *M3* contacts have closed and are in good condition.

There Are Other Tests You Can Do To Verify:

- the exact starter drive position at which the *M1* contacts close
- the exact starter drive position at which the *M3* contacts close
- the starter will not run-on after the key switch is released
- that you won't get a “click, no start”
- the amount of reserve “burnoff” for each set of contacts.

But since this article is already too long, I will save that stuff for some other time.

A Couple of Things to Avoid

I've seen an M50 starter core come in with a custom jumper strap someone had put across the *M1* and *M3* solenoid terminals to reduce certain problems, while still using the older 17-degree spline armature (see *Figure 12*). The drive was badly milled as a result of a tooth-abutment/grinding problem. If they had used a 32-degree spline armature instead, it probably would have been fine. This is what the newer M127 starters use, together with the single pair of contacts in the solenoid. The sharper spline angle gives the drive more twist as it is thrusting forward, helping clear the tooth-abutment scenario, should it occur. In my opinion, the M127 design with the single-contact solenoid and 32-degree splines will last longer under the low-voltage conditions so common on older equipment.

Also, be careful of some aftermarket “new” starters. I have seen some that have the single-contact solenoid, but still use the earlier armature design with 17-degree splines. These will be more prone to the tooth-abutment/grinding problem.

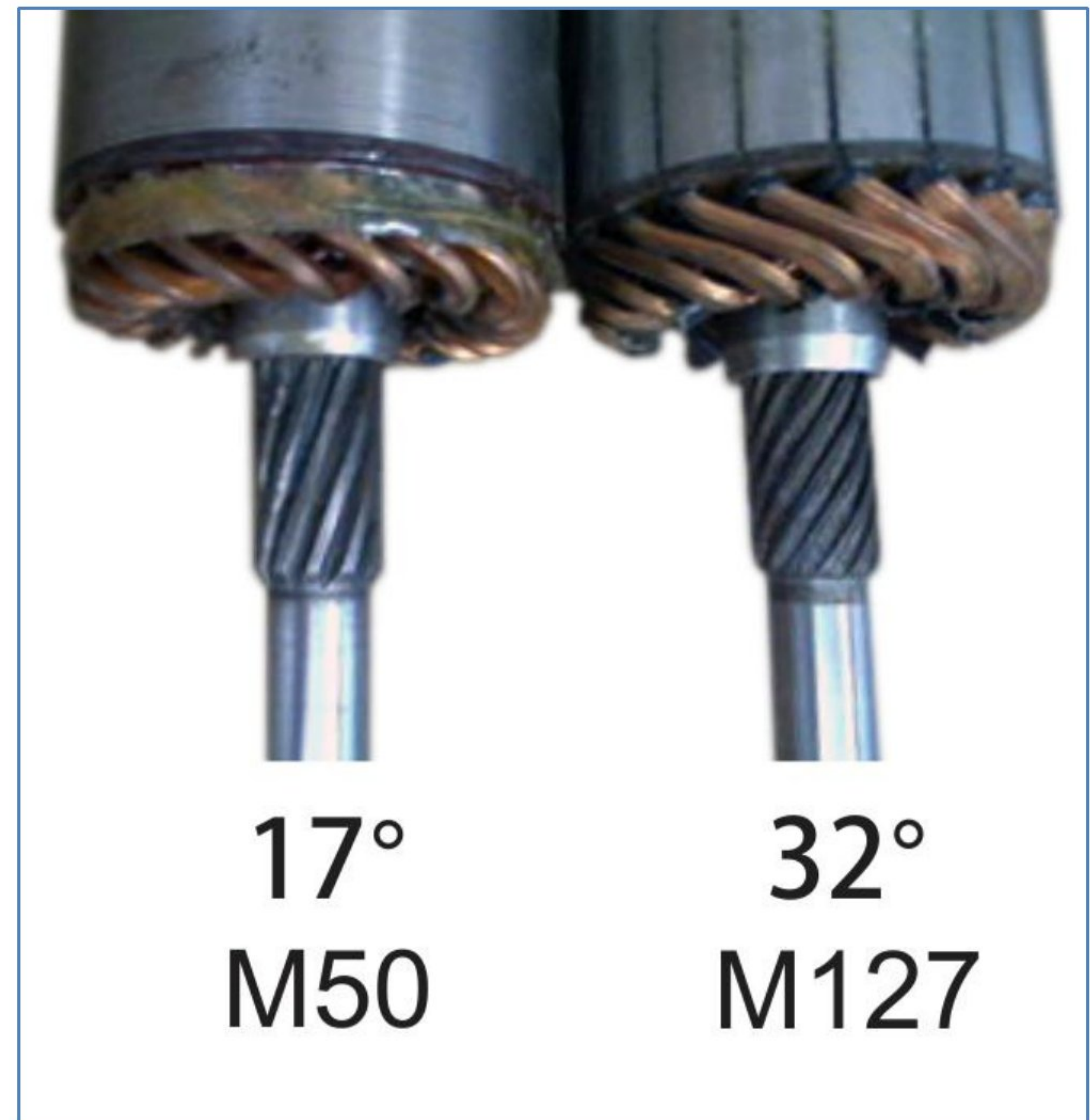


Figure 12—M50 and M127 Armatures

Conclusion

When you see a single burned field coil on one of these units, check for fouled *B+* to *M3* contacts or incorrect pinion clearance.

There are more schemes for soft-start out there, but studying the M50 with double contacts will help you with some basics, so that you can become the go-to guy for this kind of stuff.

Article created by Nathan Unger (ASI Rebuilders) in collaboration with Wes Grueninger (Auto Lab)

¹Voltage-Drop Testing—Common problems can be detected

²A detailed explanation of Kirchhoff's Rules can be found at:

<http://electron9.phys.utk.edu/phys136d/modules/m6/kirchhoff.htm>