AeroElectric Connection
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Shower of Sparks Ignition

> **Preliminary Publication**
> The topic of SOS ignition systems came up on the AeroElectric-List and I found this article I started back in '95 and for a variety of reasons, didn't get completed. I'm making the article available in its present state along with a number of drawings. Please keep in mind that it needs some figures added and may have other errors.

From time to time, a reader will call asking about replacing a "Shower-of-Sparks" (SOS) magneto with an impulse coupled magneto. When I ask why, the story often centers around the recommendation of a mechanic or flying buddy. Seems that SOS systems are not highly regarded in some circles. A bit more conversation reveals that the person giving advice probably didn't understand how the system works and certainly didn't have a grasp on it's advantages.

Let us consider the difference between impulse coupled and battery augmented, and SOS systems. While an engine is running, the two systems are indistinguishable from each other. A single set of points timed 20-30 degrees before top dead center delivers a spark to the appropriate cylinder via a magnetically charged transformer (inductor) and a distributor.

Cranking the engine is a different situation. First, the engine is turning at about one tenth it's cruise RPM; a magneto's output voltage is firmly linked to the speed at which an internal magnet flies past a coil of wire. Cranking RPMs are not conducive to strong sparks from a magneto. Second, and VERY important, the spark must be retarded to some point at or past top-dead-center on piston travel. Ignition of an explosive mixture will drive the engine in the wrong direction producing the dreaded "kick back" . . . very hard on engines and accessories.

With an impulse coupled magneto, a spring and cam mechanism locks the magneto drive shaft at some part of its rotation ***before*** the points would be opening to deliver an advanced spark to a running engine. As the engine moves forward, a spring in the coupler is wound against the locking mechanism until such time as a cam causes it to be released. The spring unwinds quickly causing the magneto to "catch up" to the engine. By now, the engine has rotated 20 or so degrees further than normal cylinder firing time. The spring-driven shaft rapidly catching up with normal engine timing produces a short boost to the magneto's instantaneous shaft velocity. The retarded release of the coupler's mechanism allows the spark to occur much later in the engine's rotation cycle. This relatively simple system overcomes the magneto's worst shortfall (no or poor spark at cranking RPM) and best yet, it works on simple airplanes with no starter or electrical system.

An impulse-coupled sparks are not great sparks. Some engines (especially BIG ones) start poorly or not at all on the energy delivered to the plugs by an impulse coupled magneto. In days gone by, straight coupled mags were installed in tandem with a Kettering style, battery powered ignition system. A friend of mine once owned a C-190 with a combination of straight coupled magneto and Kettering (pure battery-powered automotive) ignition systems. The engine started well using the battery ignition.

The "secret" of an alternative magneto starting system is revealed in a Cub Scout merit badge project, a doorbell buzzer. Figure 1 illustrates an electro-magnet formed from a coil of wire positioned to so as to exert a magnetic tug upon an armature made of steel. In my Cub Scout project of many years gone by featured a coil wound on a bunch of finish nails clustered tightly together on a piece of pine. An "armature" fabricated from flashing metal is fitted with a spring hinge and electrical contacts in series with battery power to the coil.

The "spring" tends to hold the contacts closed while a magnetic tug will force the contacts open. With the coil de-energized, contacts are closed and battery power flows into the coil. The resulting magnetic field pulls on the armature and opens the contacts, interrupting current to the coil. The cycle rapidly repeats emitting a buzzing sound in the process. Audible buzzing was a mechanical manifestation of the physics involved but a curious, more silent phenomenon occurs at the same time. Voltage induced in a wire is directly proportional to the speed at which a magnetic field builds or drops close proximity to the wire. Obviously, as the buzzer contacts open, the circuit is broken and the magnetic field collapses very quickly inducing a short "spike" of voltage in the buzzer coil of up to 100 volts or more! Many an unwary Cub Scout (including yours truly) was surprised to fine that his little flightlight battery powered physics demonstration could bite!

Recalling the days of hand cranked, Model T Fords the ignition "coil" was a wooden box which contained a soft iron transformer core wound with a few turns of heavy wire as a "primary" and lots of turns of fine wire as the "secondary". A relay armature and set of points were fitted to the end of the box were the transformer core protruded through. Normally closed points on the relay armature would be opened when the armature was attracted by electromagnetism in the transformer core. The points were hooked in series with the primary winding.

When battery voltage was applied, the contacts would open when the primary current built up thus breaking the supply current and allowing primary current to fall quickly to zero. Of course, this allowed the points to re-close allowing the cycle to repeat. Sound familiar? As long as voltage were applied, the coil would "buzz". Each break in primary current allowed a rapid fall in magnetic field current which generated a voltage in the secondary of several thousands of volts - plenty of snort for lighting a gasoline fire. The operative features of this quaint automotive ignition offered a solution to hard starting aircraft engines some decades later.

Figure 2 illustrates a schematic representation of the magneto. Lacking battery power, a permanent magnet rotated by the engine is used to induce a magnetic field in the transformer core. The new wrinkle in this case is provided by a cam operated switch, commonly called "points". When closed, the points place a dead short on the transformer's primary winding. The short effectively pours molasses in the path of a magnetic field which is otherwise free to build and fall. Rapid field fluctuations are prevented as long as the points are closed. The points are opened by a cam driven in proper synchronization with engine rotation so as to provide a single spark at the right time. Early on we acknowledged the magneto's poor performance as an ignition source for starting. At cranking speeds, output voltage is small and unless fitted with some sort of delay mechanism (impulse couple) the spark will occur well before top dead center causing the dreaded “kick-back". Indeed, many early motorists suffered damage to body parts after failing to retard the spark control on the steering column before attempting to start the engine with a hand crank.

Figure 3 illustrates a combination of all the points discussed so far. Suppose we fabricated a low voltage buzzer powered from the ship's battery. Instead of grounding the buzzer to airframe, let's connect it to the magneto points via the standard "p-lead" connection. Further, let's add a second set of points timed to open after the engine's pistons pass through top dead center. The second, retarded set of points are simply wired in parallel with the normal, advanced set. Now, if battery voltage is applied to this circuit, the "buzzer" will commence to do its thing, inducing a current in the circuit that rises and falls several hundred times per second. While either set of points is closed, the buzzer's effects are not felt by the magneto coil windings.

Indeed, even after the normal or "advanced" points open, the retarded points are still closed. Only after both sets of points open, does the rapidly modulated buzzer current get applied to the magneto's primary winding. Now, each time the buzzer contacts close, current flowing in the magneto primary "charges" the coil.

As the buzzer's contacts open, current drops to zero allowing rapid collapse of any previously established magnetic field. Just as in early automotive “buzz box” ignition systems (and later Kettering point-and-coil ignition systems), A high voltage pulse is induced in the secondary. When conducted to the proper plug by a distributor rotor and if conditions are right, the mixture in the cylinder ignites and the engine starts.

Now, here's the best part. The first spark arrived at or near top dead center of piston travel when cylinder pressures are highest. If the first spark doesn't achieve ignition, another is sure to follow a few milliseconds later when pressures are lower. Plugs are easier to fire as cylinder pressures drop. It should be obvious now that unlike the impulse coupled magneto or even a Kettering points-and-coil ignition system, an SOS system offers a series of sparks affording many chances for a cylinder to light off for each transition through compression.

Admittedly, the later the fire lights, the weaker will be the resulting explosion but, a WEAK explosion is much better than NO explosion. Given that SOS ignition performance is not pegged to rotational velocity of the magneto shaft, cranking speed is no longer critical. Ever watch an old aviation movie wherein some very large engines are started by pushing a prop by hand through a single blade? That engine was fitted with one-hell-of-an impulse coupled mag OR a shower of sparks ignition system.

Figures x and x illustrate typical wiring for two Shower-of-Sparks applications. The first is typical of single engine airplanes with OFF-LEFT-RIGHT-BOTH-START key switches. This type of ignition switch can be fitted with an extra function which parallels the retard points with normal points in the "start" position. This terminal is generally labeled "LR" on the back of the switch. Another function connects battery power to the buzzer (commonly called a "vibrator") only during a start. This terminal is generally labeled "BO". A little study of the switch functions chart and associated wiring will reveal the interplay of battery power, vibrator, and retard points in orchestrating what has to be the most effective starting scenario for magneto fitted engines.

Light twins don't use key switches so a different approach is called for. SOS vibrators for twins have an additional relay included for the purpose of managing the special connections required for starting. In this case, voltage applied to the starter solenoid also energizes the SOS relay to apply voltage to the vibrator and connect the retard points in parallel with the advance points during cranking. The more expensive, relay fitted vibrator can be made to service a single engine airplane with appropriate key switch functions. However, the simpler, relay-less vibrator cannot be used on a light twin without adding an outboard relay or using a special function toggle switch to handle the extra switching duties.

It should be obvious by now that a properly functioning SOS ignition system has VERY desirable qualities. Since there ain't no such thing as a free lunch, we'd better touch on the down-side of SOS ignition. First, if you think "kick-back" from a worn impulse couple is bad, wait 'til you crank an engine with worn or disconnected retard points in an SOS system! Further an airplane fitted with SOS magneto cannot be started by hand since the SOS system is battery powered and effective only while the cockpit controls are in the start position. (See last wiring diagram for the Mooney solution)

In cases were a battery is too low to actually crank the engine, it might very well have enough energy to power the SOS vibrator. A starter disable switch would allow the SOS vibrator and retard points to be made active without energizing the starter. When the man on the prop yells “contact” and hears the vibrator buzzing away on the firewall, a gentle nudge of the propeller through top-dead-center will light ‘er off. Another suggestion is to make provisions for a small, aux battery to power the SOS system through special "hand propping" circuitry in lieu of taking power from the main ship's battery.

Given that few mechanics really understand the words you've just read, it behooves you to have a plan of action when your SOS system fails to deliver its usually sterling performance.

Symptom: Engine cranks and starts and runs but dies on left mag only.

Your left mag advance points may be unhooked. The engine will start on the retard points and run on the right mag when the switch is released to BOTH. Check the mag's advance points and associated wiring.

Symptom: Engine fires and kicks back.

DON'T GO ANY FURTHER until retard points, ignition switch, relay and/ or associated wiring is checked out. An SOS system with open retard points circuit is capable of precipitating severe starter and/or engine damage. Obviously, attempting to hand prop this engine could cost some fingers too . . . .

Symptom: Engine starts but runs very poorly on left mag only.

This would be a symptom of a stuck relay in a light twin SOS system . . . retard points are always hooked in causing left mag spark to be always very late.

Symptom: Engine cranks but fails to show any indication of ignition.

Can you hear the vibrator buzzing? If you can't hear it normally, try disconnecting the small wire from your starter solenoid so that the engine stays quiet when you place the switch in START position. While in the START position, the vibrator should be audible. If your vibrator is fitted with an internal relay, an audible "click" should be heard before the "buzz" starts. If no "buzz" is present, check wiring paths marked x, x, and x in Figures z and z.

Also, the CONDENSER could be shorted. The easiest way to check the condenser is to see if the magneto timing can be checked with a timing light. A shorted capacitor prevents the timing light from illuminating at any time.

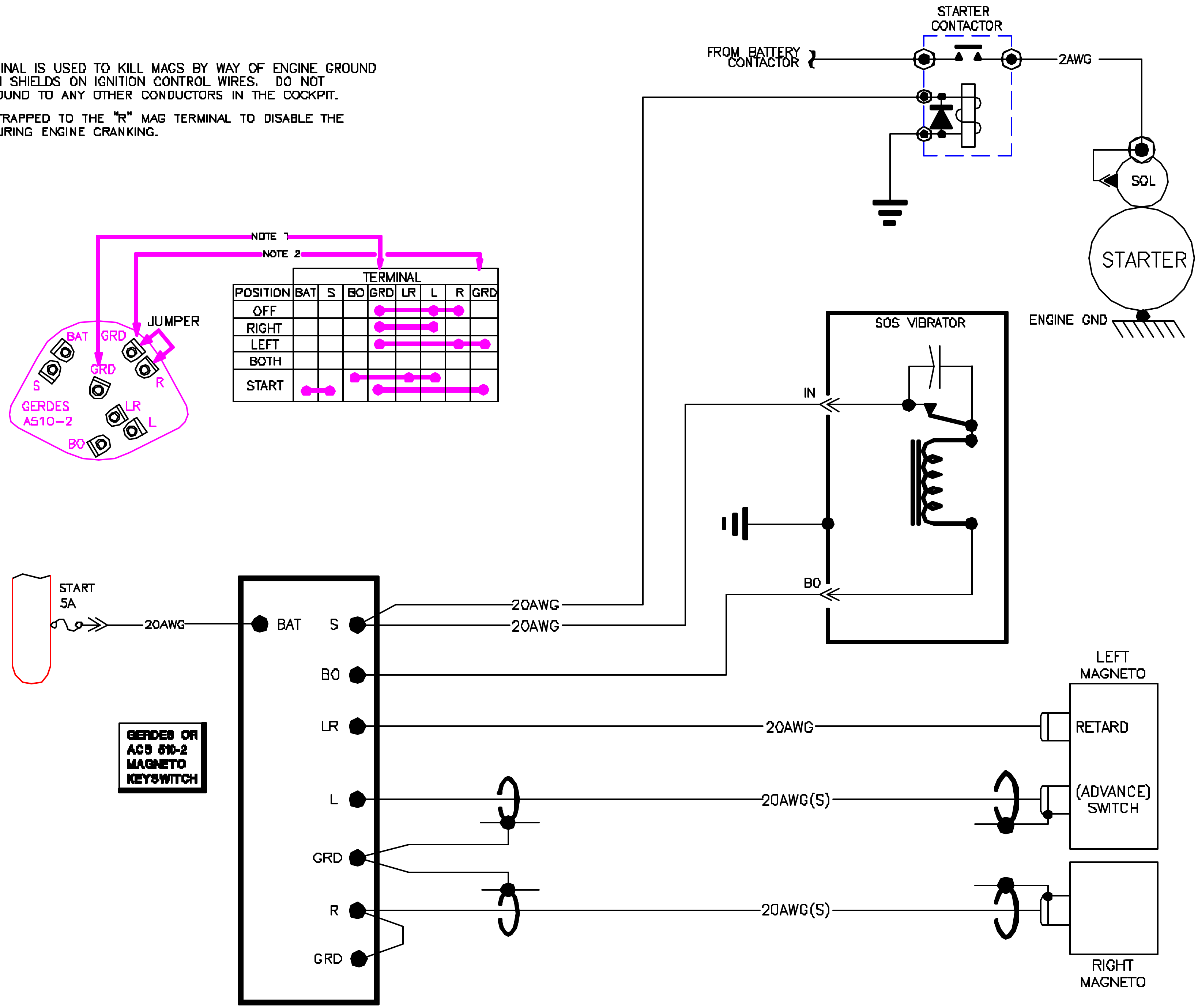
Conclusion:

If it were MY airplane and I had an opportunity to choose between impulse coupled and SOS magneto, I'd readily prefer the SOS system. An SOS system gets an engine started like no other magneto can. It's a bit more complicated electrically but much simpler mechanically than its impulse coupled cousin. Virtually all of it's failure modes can be trouble shot without pulling the magneto from the engine. All ya gotta do is understand how it works . . . . .

NOTES

1. THIS GROUND TERMINAL IS USED TO KILL MAGS BY WAY OF ENGINE GROUND SECURED THROUGH SHIELDS ON IGNITION CONTROL WIRES. DO NOT CONNECT THIS GROUND TO ANY OTHER CONDUCTORS IN THE COCKPIT.

2. THIS GROUND IS STRAPPED TO THE "R" MAG TERMINAL TO DISABLE THE RIGHT MAGNETO DURING ENGINE CRANKING.



POSITION	BAT	S	BO	GRD	LR	L	R	GRD
	TERMINAL							
OFF				●		●	●	
RIGHT				●		●		
LEFT				●			●	●
BOTH								
START	●	●	●	●	●	●		●

The AeroElectric Connection
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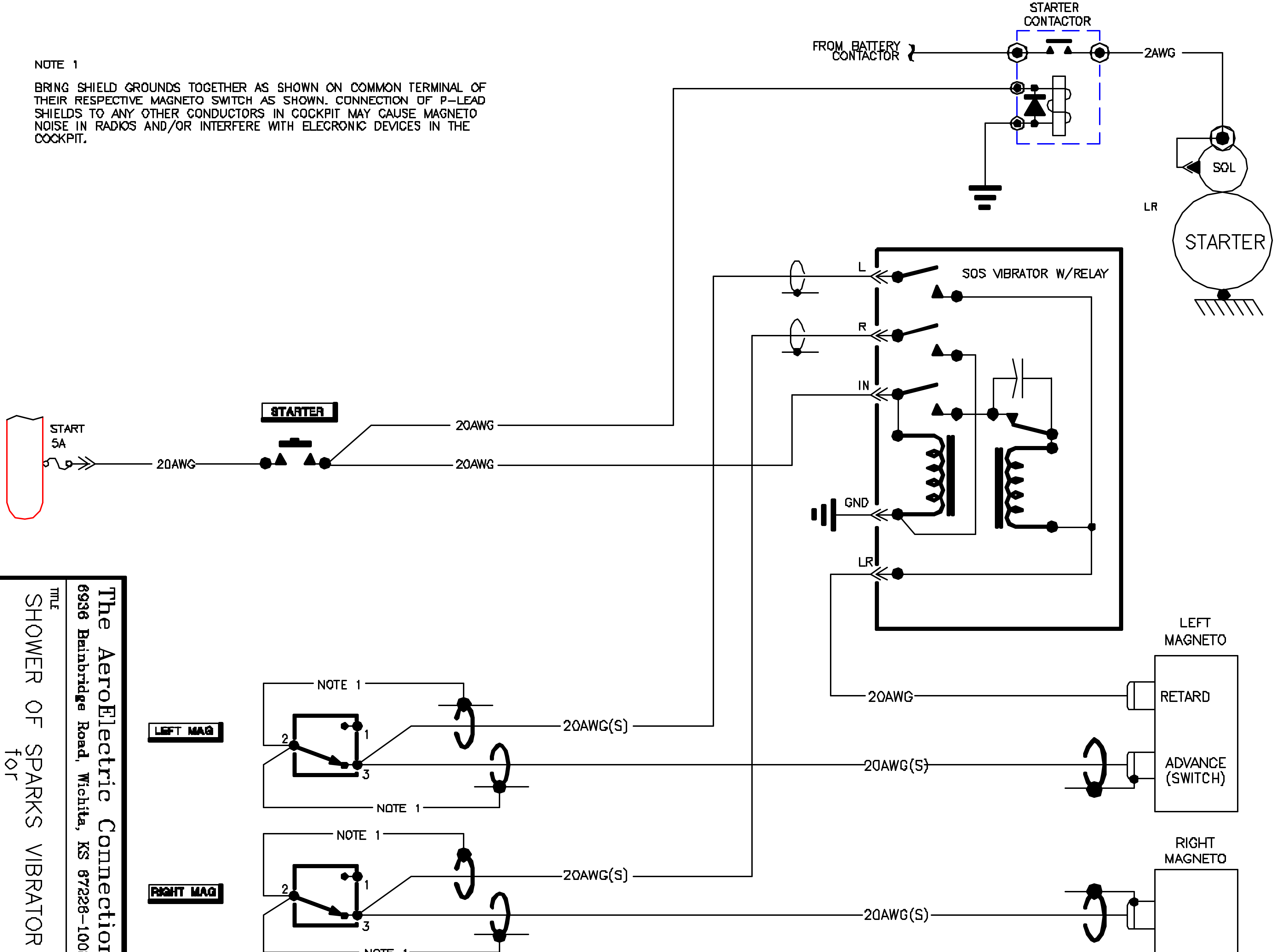
TITLE
SHOWER OF SPARKS VIBRATOR for KEY SWITCH CONTROLLED MAGNETOS

REVISION A | DATE 03/01/95 | PAGE 1 OF 3

NOTE 1

BRING SHIELD GROUNDS TOGETHER AS SHOWN ON COMMON TERMINAL OF THEIR RESPECTIVE MAGNETO SWITCH AS SHOWN. CONNECTION OF P-LEAD SHIELDS TO ANY OTHER CONDUCTORS IN COCKPIT MAY CAUSE MAGNETO NOISE IN RADIOS AND/OR INTERFERE WITH ELECRONIC DEVICES IN THE COCKPIT.



The AeroElectric Connection

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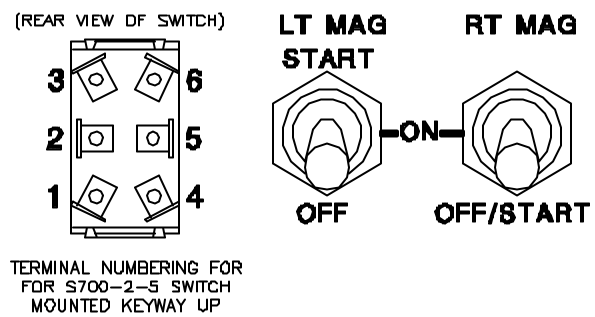
TITLE

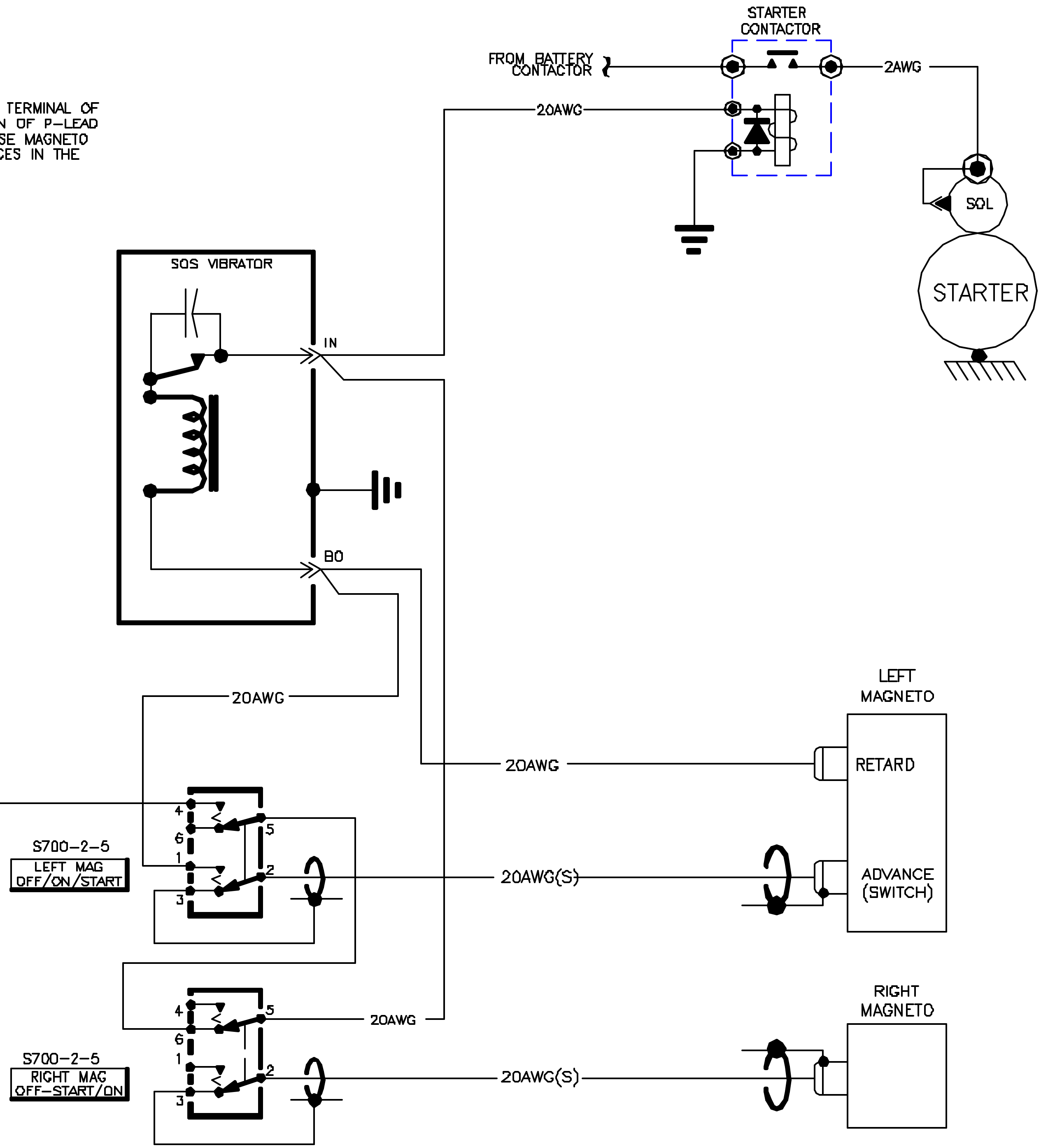
SHOWER OF SPARKS VIBRATOR for TOGGLE SWITCH CONTROLLED MAGNETOS

REVISION A	DATE 03/01/95	PAGE 3 OF 3

NOTE 1

BRING SHIELD GROUNDS TOGETHER AS SHOWN ON COMMON TERMINAL OF THEIR RESPECTIVE MAGNETO SWITCH AS SHOWN. CONNECTION OF P-LEAD SHIELDS TO ANY OTHER CONDUCTORS IN COCKPIT MAY CAUSE MAGNETO NOISE IN RADIOS AND/OR INTERFERE WITH ELECRONIC DEVICES IN THE COCKPIT.





REV -B- 09/01/00
REV -A- 09/15/97

The AeroElectric Connection
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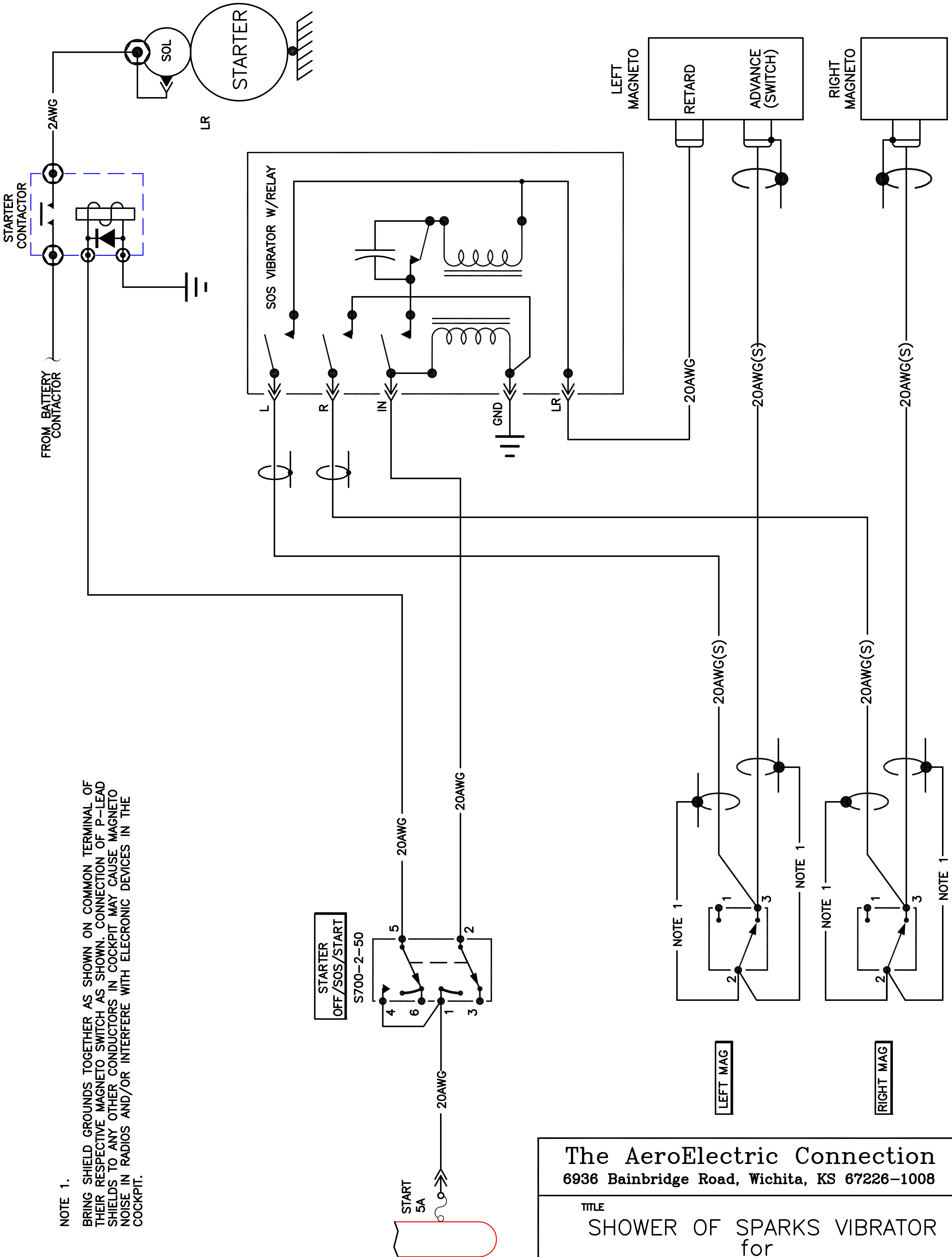
TITLE
SHOWER OF SPARKS VIBRATOR
for
TOGGLE SWITCH CONTROLLED
MAGNETOS

REVISION B	DATE 03/01/95	PAGE 3 OF 3



NOTE 1.

BRING SHIELD GROUNDS TOGETHER AS SHOWN ON COMMON TERMINAL OF THEIR RESPECTIVE MAGNETO SWITCH AS SHOWN. CONNECTION OF P-LEAD SHIELDS TO ANY OTHER CONDUCTORS IN COCKPIT MAY CAUSE MAGNETO NOISE IN RADIOS AND/OR INTERFERE WITH ELECRONIC DEVICES IN THE COCKPIT.

The AeroElectric Connection
6936 Bainbridge Road, Wichita, KS 67226-1008

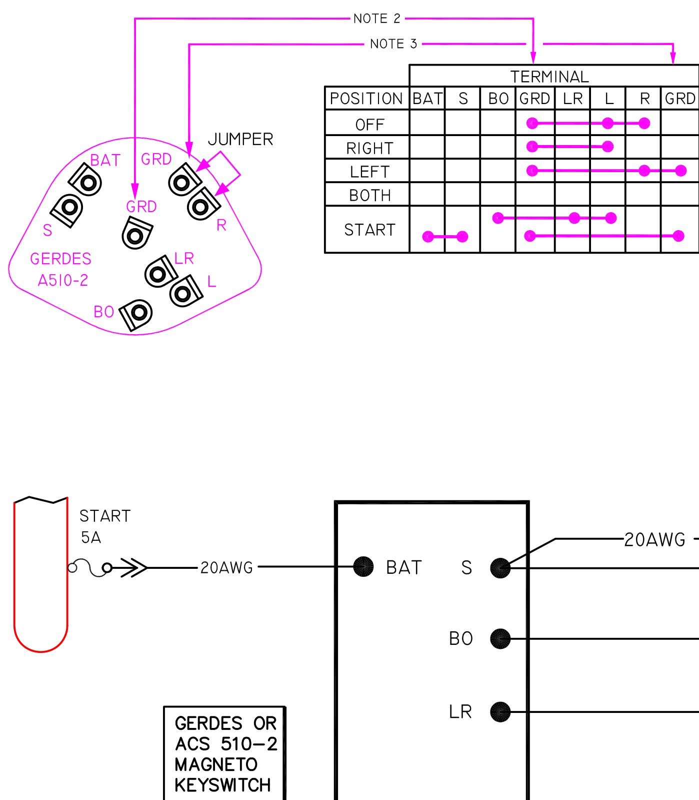
TITLE

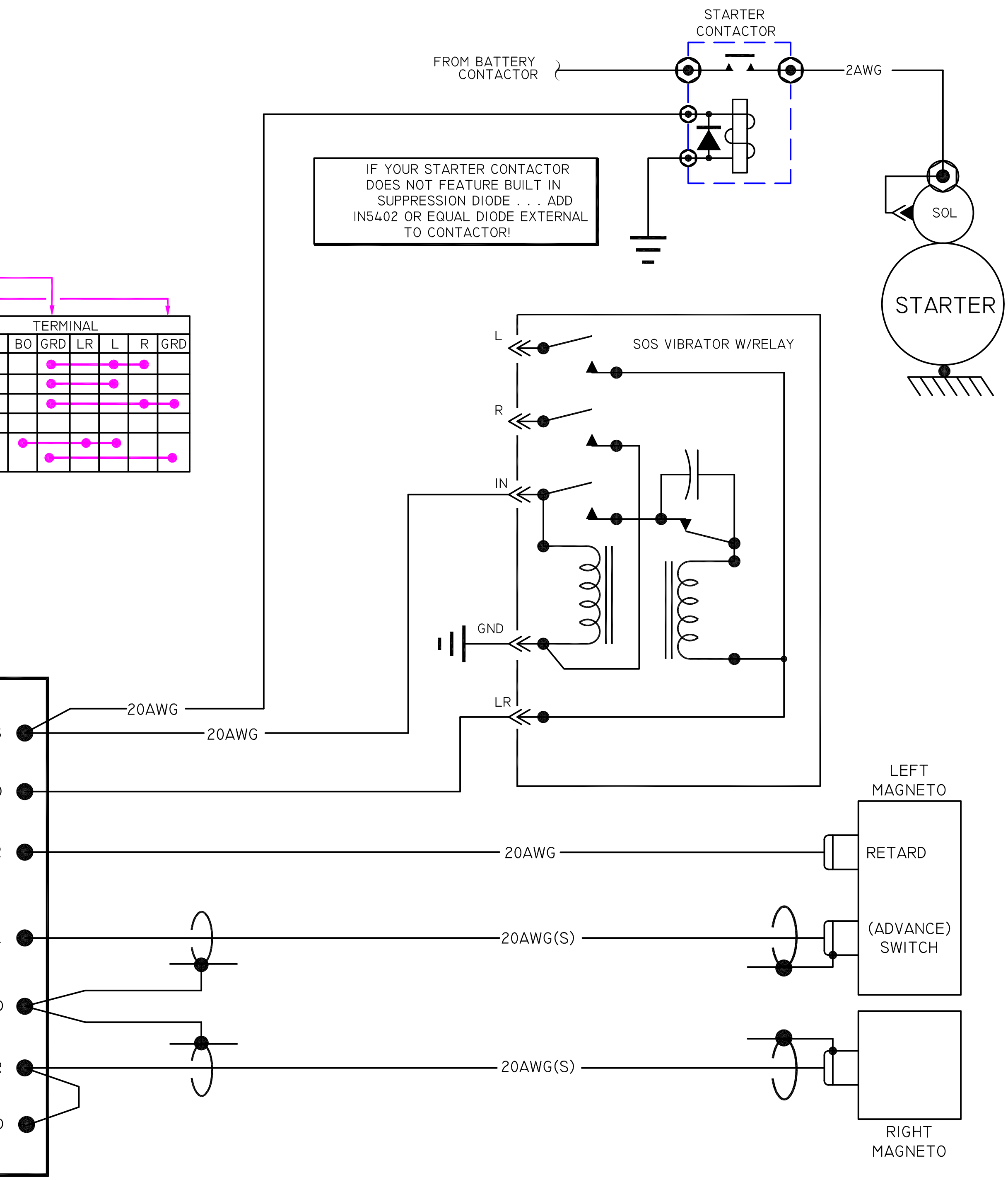
SHOWER OF SPARKS VIBRATOR for TOGGLE SWITCH CONTROLLED MAGNETOS (Progressive Switching)

REVISION	DATE 11/21/03	PAGE 4 OF 4

NOTES

1. THE SHOWER OF SPARKS VIBRATOR WITH A RELAY IS NEEDED FOR TOGGLE SWITCHES AS OPPOSED TO THE LEGACY OFF-LEFT-RIGHT-BOTH-START KEY SWITCH. THIS RELAY VERSION MAY BE USED WITH A KEY SWITCH BY IGNORING THE VIBRATOR'S FEATURES UNIQUE TO TOGGLE SWITCH CONTROLS.
2. THIS GROUND TERMINAL IS USED TO KILL MAGS BY WAY OF ENGINE GROUND SECURED THROUGH SHIELDS ON IGNITION CONTROL WIRES. DO NOT CONNECT THIS GROUND TO ANY OTHER CONDUCTORS IN THE COCKPIT.
3. THIS GROUND IS STRAPPED TO THE "R" MAG TERMINAL TO DISABLE THE RIGHT MAGNETO DURING ENGINE CRANKING.





The AeroElectric Connection

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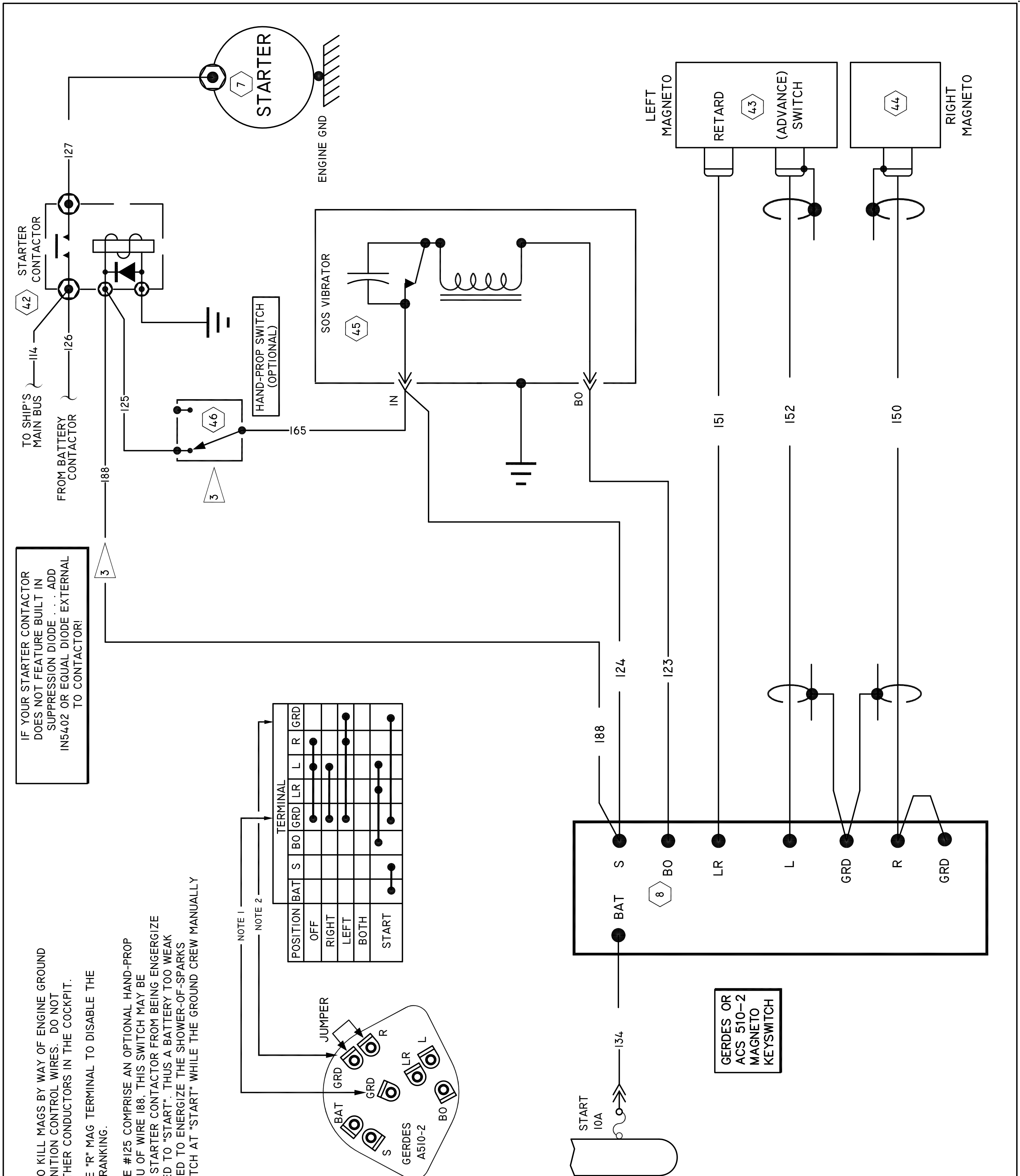
TITLE

USING O-L-R-B-S KEY SWITCH
WITH
SHOWER OF SPARKS VIBRATOR
FOR TOGGLE SWITCHES (RELAY)

REVISION A | DATE 01/30/16 | PAGE 5 OF 5



POSITION	BAT	S	BO	GRD	LR	L	R	GRD
OFF				•		•	•	
RIGHT				•		•		
LEFT				•			•	•
BOTH								
START	•	•	•	•	•	•		•

NOTES

1. THIS GROUND TERMINAL IS USED TO KILL MAGS BY WAY OF ENGINE GROUND SECURED THROUGH SHIELDS ON IGNITION CONTROL WIRES. DO NOT CONNECT THIS GROUND TO ANY OTHER CONDUCTORS IN THE COCKPIT.
2. THIS GROUND IS STRAPPED TO THE "R" MAG TERMINAL TO DISABLE THE RIGHT MAGNETO DURING ENGINE CRANKING.
3. SWITCH #46, WIRE #165 AND WIRE #125 COMPRISE AN OPTIONAL HAND-PROP FEATURE. WHEN INSTALLED IN LIEU OF WIRE 188, THIS SWITCH MAY BE OPENED TO PREVENT THE STARTER CONTACTOR FROM BEING ENGERGIZE WHEN THE KEY-SWITCH IS ROTATED TO "START". THUS A BATTERY TOO WEAK TO CRANK THE ENGINE CAN BE USED TO ENERGIZE THE SHOWER-OF-SPARKS SYSTEM BY HOLDING THE KEY-SWITCH AT "START" WHILE THE GROUND CREW MANUALLY PROPS THE ENGINE BY HAND.

A SPECIAL IMPLEMENTATION OF S.O.S. IGNITION FOUND ON SOME MOONEY AIRCRAFT THAT FEATURES A "HAND PROP SWITCH". THE STARTER CONTACTOR IS DISABLED SO THAT THE SOS SYSTEM CAN BE INDEPENDENTLY ENERGIZED BY HOLDING THE KEY IN THE 'START" WHILE THE PROP IS SIMPLY PULLED THROUGH T.D.C. AS SOON AS THE RETARD POINTS OPEN, THE ENGINE COMES TO LIFE.

MOONEY M20 STARTER-IGNITION SYSTEM