**Electronic Ignition Systems for Radial Engines**

By Craig Payne

In today’s piston powered world, Electronic Ignition (EI) is the standard. Standard everywhere except in the aviation world where magnetos still dominate. Magnetos survive because they generate their own power and require no external power source. Some of today’s EI systems can now say the same thing; but all aircraft EI systems still require some external power to start, even if it is a small 9 volt battery.

The case for EI is superior sparking from high voltage and timing control, light weight, and the ability to build in features such as RPM limiting, manifold pressure (MAP) regulation of timing, and monitoring of various engine conditions.

**The Stock System**: Both the Huosai and Russian engines come with conventional radial engine ignition systems. These magnetos are large, heavy and do a good job of providing spark to two spark plugs in nine cylinders that turn up to 2900 or more RPM. If maintained properly, the stock system will last the life of the engine. “Maintenance” includes keeping the wires, spark plug wire fittings and elbows clean and dry as well as cleaning spark plugs that cost from $17 to $37 each in 2012 dollars.

To address maintenance and cost issues, some folks like Dennis Savarese have made a DIY aftermarket wire and automotive spark plug conversion kit widely available. With help from Richard Goode, these sets have EASA approval in the European Union. In the U.S. no such explicit approval is required and hundreds of kits have been installed worldwide.

To be fair, there are experts who work on these engines that maintain such modifications are not necessary. While I can agree with that position, I am still in pursuit of greater efficiency; it’s what I do. I also agree that the average CJ-6 or Yak operator does not need any more performance than the stock airplane provides. But of course, we have Needs and then we have Wants. As pilots, we all want more power but as owners we like better fuel economy and lower operating costs. Somewhere in between is the compromise.

**Modified Engines**: One of the recent trends I have seen at events like formation clinics and Oshkosh, is that more owners are having their engines reworked to improve performance over the stock engines. The trend is towards custom pistons, higher compression ratios, custom exhaust, automatic advance magnetos on M-14’s with automotive spark plug conversions, etc. Some owners have gone to aftermarket fuel injection and dyno-tuning as well.

While all of this is taking place, the stock magneto system, even with racing wire and motorcycle spark plugs isn’t keeping up with the potential these engines offer. Set the spark plug gap too wide and misfiring occurs at altitude. Proving the value of EI is easy, simply switching to a higher energy system on a stock engine yields a smoother, and slightly higher RPM idle on the electronic system, compared to the magneto. I have found that replacing only one magneto is all that is needed to obtain a good benefit. At takeoff power, another 30 to 50 RPM develops, perhaps requiring a governor and/or blade angle adjustment. Performing a spark plug “read” is more telling; even the plugs on the magneto side run cleaner and develop that nice tan color that engineers like. This is the result of cleaner burning and better fuel efficiency which also results in cleaner oil as well since there are less combustion by-products to contaminate the oil.

**E-Mag, Light Speed Engineering and Electroair System Features for Flat Engines**

Most of these systems have Certified and Experimental models and are of the distributor-less, “wasted spark” type. Each cylinder fires on both compression and exhaust strokes from coils installed on a cylinder pair. Only an even number of cylinder configurations are supported. Rotax engines have a similar system built in.

Battery power is required to start each, but the E-Mag will hand prop using a 9-volt battery. The E-Mag generates its own power after start and will run without external battery power while the Electroair and Light Speed systems use battery/alternator power to run. Manifold sensors on each unit help regulate spark timing. Timing is retarded at start-up and advances to about 24° to 28° Before Top Dead Center (BTDC)at full power settings. Manifold pressures under 24”, such as those found at economy cruise at altitude, will further advance spark to 39° to 43°, depending on the system. This is what the old vacuum dashpot did on automotive distributors. Lean and low air density mixtures burn slowly and require a lot of spark advance to keep peak cylinder pressure at 11° After Top Dead Center (ATDC).

The E-Mag offers multiple strikes per through 20° of spark plug firing, up to five strikes at idle. The Electroair system fires a continuous spark. Voltages of 70KV are typical, firing spark plug gaps of up to .035”. The Electroair draws about 1-¼ amps while a running E-Mag takes no battery draw. Light Speed has a 6 cylinder unit that draws up to 2.1 amps and outputs 120 millijoules of spark energy. Either single spark or multiple spark units are available from Light Speed.

Other features include RPM limiting, and monitoring of unit operation. Spark advance programming is usually done at the factory to engine specs and is not field programmable. Manufacturers claim that 75% to 85% of EI benefits are achieved with only one of the units installed with a magneto. Additional benefits from dual EI systems don’t manifest themselves unless operating in mid-teen’s flight levels where thinner air requires a powerful spark. Note that these systems cost as much and more than the magnetos they replace.

**The Nine Cylinder Problem**: Basically the market is too small to justify a lot of investment. Most existing automotive systems are designed for 8 cylinder operation, programmable for 6 and 4 cylinder engines. 9 cylinders fire once each in 720° rotation, or at 80° of crank interval rather than 90° rotation that 8 cylinders require. Thus 2900 RPM on an M-14P requires as many sparks as 3262 RPM on an 8 cylinder. I’m talking about the 4-cycle engines here, not 2-strokes or other configurations. Since many V-8 systems are designed for operation up to 10,000 RPM, some ignition components are readily adapted to a low-RPM nine cylinder radial, they will just “think” that it is an eight cylinder system being controlled.

**EI Basics**

 **Wiring**: I doubt whether any electronic system could work well with standard wires and harness. Absolutely, an electronic ignition system will require high performance “wrapped” wire over a silicone core to suppress Electromagnetic Interference (EMI) and Radio Frequency Interference (RFI) as well as safely carry the high voltage generated by the system. Solid core wire is bad for EI and may disrupt the controller as well as overheat some components due to inherent low resistance. 8mm “Spiro-wound” silicon core wire, 8.5mm or even 10+mm wire will safely carry spark energy without radio interference, “flashover” to adjacent wires, or suffer energy leakage (if installed correctly).

**Triggering**: An energy pulse from the controller may be triggered many different ways, from crank position magnetic, optical or Hall Effect devices. Stock magneto points will also do the job as only low voltage is being used as a trigger signal.

**Controller**: A controller or “ignition box” generates the spark pulses and sends multiple spark pulses to a coil or coils. Features may include RPM limiting, developed primarily to protect high-reving engines from missed shifts, fixed or programmable spark advance curves, auto retard for starting, MAP, RPM, and CHT sensing for active spark advance control, and operator-controllable retard/advance control. Of these, active spark control will do the overall best job, but at the price of added complexity and cost.

**Power Source:** Automotive based systems use the battery and electrical system to power the controller; other systems such as the E-Mag include an internal alternator to generate the necessary power, independent of the primary electrical system.

**Coil/Distributors**: Either a single high energy coil at 70:1 or 100:1 turns ratio is required with a distributor, or multiple coils, one per cylinder; similar to WW-II multi-row radials is required for distributor-less systems. Spark pulses from the coil are routed to either a single module per spark plug or a distributor. ***An existing magneto can be easily modified to do this job***. If the Right-side mag is chosen for conversion, then the Left mag starting function is preserved with good old-fashioned redundancy if the conversion fails for any reason.

**Magneto Switch Control**: I prefer using the existing magneto cockpit switch to control the electronic system, as well as one standard magneto, keeps the system simple for a pilot to operate as there are few changes from normal operation. To accomplish this, an isolation relay can be used to invert the Grounded/Ungrounded function to control the ignition box as if it were a magneto. Thus, the pilot operates the system exactly as a stock system. Only one extra power “On/Off” switch is required for switch flow management and that is to turn on the 12V trigger power supply.

Full electronic systems with no magneto can use conventional switch and circuit breakers to perform the same task as a magneto switch.

**Power Supply**: ***Now for the Bad News*** - the key drawback to using automotive aftermarket components is that they are all designed for 12V systems, some are advertised to work at 18V but none advertise 24V- 28V. Therefore a 12V power supply may be needed for some components. The STC’d systems will run on 24V, but a pretty steep premium must be paid and none are for engines with more than 6 cylinders.

**Current Offerings for Vendenyev –type Engines**

**Gemini System Features**: Developed by Barrett Precision Engines and marketed by both Jim Kimball Enterprises and BPE for the M-14 series of engines. System features include: Dual Hall Effect triggering, regulated spark control, ignition advance curve, underspeed and overspeed protection via RPM limiting, with lighter weight than magnetos and a weather proof wiring harness.

Designed from the ground up for the M-14P and M-14PF, Gemini is actually two independent systems, each with an alternator/spark unit that plugs into the magneto mount with nine coils each, installed in pairs on the intake tubes for a total of 18 coils.

**Operation:** The Gemini requires battery voltage for starting, generating multiple sparks per firing until 500 PRM is reached when each system’s internal power kicks in and one single spark is applied per NGK BUR5EB-11 spark plug. RPM and manifold pressure sensors advance the spark up to 31° in cruise power settings below N2, or 70%. At higher power settings the spark retards to the initial setting of 23° for the M-14P and 21° for the M-14PF. This is a feature to avoid detonation in modified engines using higher compression pistons. Barrett Precision Engines programs each system to match an engine. It is not field programmable by the owner/operator.

Safety features include a requirement for at least 30 RPM to fire so that hand pulling the prop through will not cause a “kick” like a mag could and an RPM limit of 3100 to guard against runaway RPM. Start switch breakers and LED indicators replace the old magneto switches. Overall, the Gemini system appears to be of very high quality, with CNC’d metal housings, shielded wires, premium connectors and aircraft quality hardware. **See Figures 1 & 2**

Owner/Pilot John Casper bought his Barrett -built M-14P powered Yak to Oshkosh this year, equipped with the Gemini system. With about 60 hours on the engine, John reports quick starts and smooth running. **See Figure 3**

As of the 2012 AirVenture event, the complete system was quoted as a field retrofit for $7700. This includes all components, wiring, panel switches, indicators and connectors. Contact Barrett Precision Engines at (918) 835-1754 or Kevin at Jim Kimball Enterprises (407-889-3451).

**Red Star Warbird Specialties**: I have a simple but robust system, designed to work with off-the-shelf automotive components and an existing right magneto. I chose the Right mag since the Left mag is hooked to the spark start coil. Both the Chinese CD-5 and “Russian” M-9F are supported. ***Stage I*** consists of a few components to replace the existing magneto coil, with automotive wire and spark plugs, and off-the-shelf racing components. **See Figure 4.**  ***Stage II*** includes my own design of a distributor cap that looks like the HEI system used in automobiles through the mid 1990’s. The cap does not require a magneto “cigarette” and spark plug wires connect directly to the top of the cap rather than slipping into drilled-out holes in the stock cap. This not only installs quicker, but ensures better wire connections than the sharp point screw-in terminals that were not designed for modern high-voltage wiring. **See Figure 5**

This system will run off of 24V simply because the RPM’s stay so low that only moderate loads are placed upon a system designed for only 12V-18V. The CD-5 magneto conversion provides automatic advance and needs no external timing control. A variety of off-the-shelf components will allow additional features. This is a system that delivers a high energy spark more powerful than what other systems offer.

***Stage I*** can be installed with your existing automotive wire conversion for under $500 for a CD-5 system (current pricing). In addition, the conversion components can be removed and stock system re-installed if the aircraft were to be sold to a country where such conversions would not be approved.

This is a multiple spark system, from 5 sparks per plug at idle to one spark at 2660 RPM. For the lower RPM Huosai engine, this means at least 2 sparks per firing at full power and cruise. Development is on-going with installations on my CJ-6 and Jim “Pappy” Goolsby’s CJ-6. Both are M-14P powered.

**RSWS System Specs:**

**Coil Input:** 530-540 volts @ 135–140 milli-joules peak.

**Coil Output Voltage:** 100:1 turns ratio output of 45,000+ volts

**Electrical system load:** 0.7A to 2.9A run current and up to 10 amps momentary during quick power changes using the stock 24V-28V system and a 12V supplementary source. Using a B&C type alternator is beneficial as some digital instruments may reset when stock generator output is reduced by very low idle speeds. This is the same reason why automotive manufacturers switched from generators to alternators years ago. However, since this type of EI system does not generate its own power, the battery and electrical system provides the energy. With an electrical charging system failure, the battery must shoulder the load. With my Gill battery; avionics draw and magneto conversion draw, the system will probably drain the battery within 10 hours. With full tanks at the cruise I power setting, my duration is limited to 5 hours.

**Other Offerings:**

There are other EI products for Yak and CJ ignition but the vendor declined input for this article.

**Electronic Ignition Pros and Cons:**

**What they will do:**

 Keep your spark plugs, combustion chamber and oil cleaner with better combustion.

 Enable better fuel efficiency by extracting more power from the fuel mixture.

 Introduce features such as RPM limiting and RPM minimum operating RPM. Control over spark timing can also be added.

 Smooth the low speed idle and prevent spark plug fouling.

**What they won’t do:**

 Correct for worn engines, misadjusted timing, leaky valves, low compression or other such maladies.

 Function with stock wiring and harness. High energy, automotive type wiring is required, same as most cars made in the last 25 years. Solid core wires will NOT work as they emit too much RFI/EFI, interfering with the electronics.

 Tolerate any poor connections or defects in spark plug wiring.

 Fire with a dead battery like the magneto system will.

 Generate more horsepower than what potential is provided by the fuel supply and induction system.

Hopefully, this article will introduce the reader to EI and help someone make informed choices about EI systems as an alternative to magnetos. As of writing, list price from multiple vendors for the Russian M-9F magneto is $1800 USD. Doug Sapp still had some new Chinese CD-5 magnetos for $1000 each as of this writing. The CD-5 makes a better platform for EI conversion due to built-in spark advance feature, which really should be called an automatic spark retard system as it functions similar to an automotive distributor. These facts of modern life will motivate me to take good care of my existing magnetos and continue to develop alternatives.