In 1994 Klaus Savier entered five races, won them all and had no failures. He hopes to keep this up.

ELECTRONIC IGNITION FOR AIRCRAFT

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Even today in 1995 the vast majority of aircraft with piston engines are using magnetos as their sole ignition source. In spite of over 100 years of experience with magnetos, extensive certifications of aircraft magnetos and quality control requirements by the federal authorities, they still fail or require maintenance, more often than any other part of an aircraft engine. Slick Service Bulletin 2-80 states that 4200 and 6200 series magnetos now being produced should be inspected externally every 100 hrs. and internally every 500 hrs. Parts subject to wear should be replaced as necessary at this time, magneto shaft bearings must be replaced every 1000 hrs. Such service bulletins are routinely supplemented with AD's requiring tests and hardware changes in addition to the regular inspections. This is typical of all magneto manufacturers and amounts to a maintenance cost which is often higher than the cost of replacement. This prompted one manufacturer to produce "Throw Away" magnetos which traded repair costs against replacement cost. The aircraft down time and cost of replacement is still a significant burden for the owner. The Light Speed engineering electronic ignition eliminates these problems by using reliable solid state electronic technology. There is no service, maintenance or inspection required for LSE ignition systems.

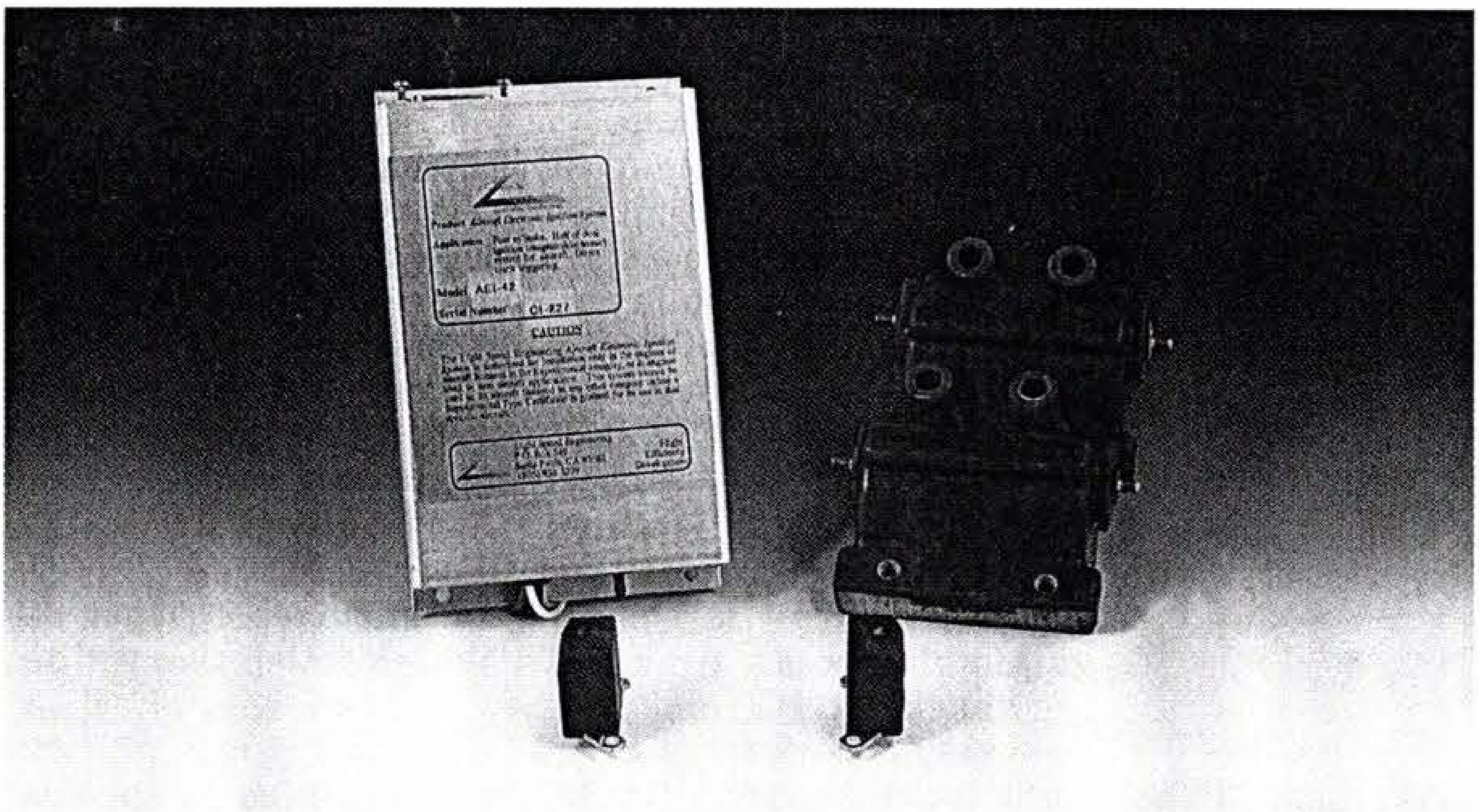
A magneto has one spark generating system and a spark distributor which directs the spark to the appropriate cylinder. This spark distribution system relies on the air in the distributor as an insulator against ground and other plug lead terminals. At altitude the insulation value of air is reduced proportional to the reduction in density (first order). The electrons at the rotor evaluate their environment for the path of least resistance. The plug terminal adjacent to the rotor tip has a higher resistance than other terminals in the distributor because the sparkplug it is connected to is at the end of the compression cycle. From this it is clear that the altitude at which a distributor misfires is lowered if the cylinder pressures are increased, i.e., by higher compression ratios, increased ram pressure, extensive porting and turbo charging. Larger gaps at the plugs and worn electrodes also contribute. On the other end, the tendency to misfire in the distributor is increased if moisture is present, the insulation value of the air is reduced by heat, altitude or ionization (a result of arcing), or the available voltage potential from the spark generating system, be it a magneto or electronic source, is increased.

The keys to improved flight efficiency: higher compression ratios or turbo chargers, reduced pumping losses, flight at high altitude, larger spark plug gaps and higher ignition voltages are all reducing the reliability of the mag and especially its distributor. Spark plug gaps of .040"-.060" are necessary to meet mileage and emission requirements in modern cars and their distributors have often doubled in size to avoid misfiring at the higher voltages required for the larger gaps. The results of a single misfiring magneto are beyond the scope of this article and are best described by an engine overhaul shop.

If the problems of a magneto operating on modern high performance aircraft are understood, it is easy to conclude that only a "distributorless" or "direct" ignition system can provide reliability, accuracy, and performance for a modern aircraft ignition system. However, a well-maintained magneto produces a hot spark at cruise rpm since its coil primary is charged with up to 70v before each firing. This provides a hotter, longer lasting spark when compared to an inductive or transistor ignition typically found on most production cars. A Capacitor Discharge Ignition, or CDI, sends 400v to the coil for each spark. If the correct coils are used, a CDI system can deliver significantly more energy to the spark plug than either a magneto or an electronic inductive ignition. Due to the characteristic fast voltage rise time of a CDI, it is virtually immune to plug fouling and can be made to strike several times in very short succession.

The total energy delivered at the spark plug for each spark sequence of a CDI is two to three times that of a magneto. An inductive type ignition system typically has a lower energy output than a magneto.

The issue of spark energy is of fundamental importance in aircraft engines, much more so than in car engines. On aircraft engines the available horsepower varies directly



The basic transistor ignition system. Two trigger coils, combination digital timing processor and transistor ignition system, and two dual ignition coils.

and noticeably with the ignition energy delivered at the plug. Here is the reason for this: a perfectly rationed fuel/air blend at atmospheric pressure is easiest to ignite and will light off from as little as 3 mj (milli joules) of spark energy. Add 160 psi of pressure from compression, some heat, an ill adjusted mixture, poor mixture distribution, and ignition energy several orders of magnitude greater is required for a successful ignition. Automotive engines today are closely monitored and controlled, they also do not operate under the high BMEP typical of high performance aircraft engines, and consequently they do not require 100 octane fuel as aircraft engines do. This means they can operate using a much cheaper lower energy ignition source. Our aircraft engines feature pilot adjusted mixture and this means it is usually set to cool the cylinders, to save fuel, or is ignored. All else being equal, minimum spark energy is required for stoichiometric fuel/air ratios. This is an ideal condition, unavailable in real life. The mixture variations between cylinders alone require much greater energy in one than the other.

Spark duration is one important aspect of the total energy delivered at the spark plug, the others being amperage (heat) and voltage (which defines the maximum allowable gap size). A long spark lingering at the gap assures ignition, since the local mixture at the plug gap may be too rich or too lean for a moment to allow ignition to occur, and more importantly it continues to ignite the mixture as it swirls past the sparkplug, thus increasing the "flame front propagation speed" as well as "ignition probability." These are the two buzz words used in the industry. Increased flame speed is especially important in large diameter combustion chambers, and this is one reason for the second sparkplug on aircraft engines.

In-flight data acquisition at LSE has revealed as much as 2 mph difference in top speed at best power mixture and .3 gph between two different high energy CDI systems. An inductive system timed exactly equal performs 3-4 mph less and burns .4-.5 gph more fuel when compared with the current multi-strike CDI sold at LSE. These tests were done on the LSE modified VariEze which shows minor changes quite clearly due to its unusually high speed to horsepower ratio. On a Cessna 150 the improvements of 2% in speed and 10% fuel flow may not be noticed, but they are there.

A magneto seems to produce slightly higher speeds than a transistor ignition system, but much worse fuel flows. This is due to the good heat of the spark but very small gap requirement. **The bottom line is: short of wearing out your spark plugs, you cannot have too much spark energy.** Any excess energy produces more power under lean or rich cylinder conditions, thus assuring best power during full rich takeoffs, best efficiency during operations past peak EGT and smoother, more powerful engine operation over the entire mixture range.

Most distributorless electronic ignition systems in use have dual ignition coils. Such a "waste spark" system fires two cylinders simultaneously, one at the end of the compression stroke and another at the end of an exhaust stroke. Obviously this does not work for radial engines since no two pistons move in parallel.

A distributorless, one coil per cylinder, electronic system, has the advantage of allowing short high ten-

This shows the transistor ignition system with the optional timing display and mag hole cover.

electronic ignition systems can accommodate a knock sensor to retard the timing when knocking is detected. However, its usefulness is questionable: aircraft engines make so much mechanical noise that it is often not distinguishable from the knocking. If knocking occurs and it is detected, most systems can retard the timing only for all cylinders since it has no information on which cylinder is the culprit. In addition, retarding the timing does not always stop the knocking, since it is often caused by preignition from glowing carbon deposits or glowing electrodes, a runaway condition.

sion wires which emit less radio noise, lower current drain per useful spark energy and reduced power loss in case of component failures. Its disadvantage is in cost, since it requires designated circuitry for each coil, which means one electronic ignition system for each cylinder from trigger to processor, ignition amplifier and ignition coil. The effect of component failures is much more benign on distributorless systems: an electronic system with dual coils (waste spark) typically loses sparks to two opposing cylinders. A system with one single coil per cylinder loses only one spark plug in case of a coil failure. A magneto or any other system using a distributor is dead when the distributor or ignition coil fails. A distributorless ignition system also allows higher output voltages to fire larger gaps at the spark plugs. Large electrode gaps are important for fuel efficiency.

An electronic system also allows the electronic delay of a trigger pulse to provide reliably retarded ignition timing for starting as well as variable ignition timing in flight, depending on rpm and manifold pressure. A crankshaft triggered electronic ignition does not suffer any timing inaccuracies as a result of gear lash. The gear lash demands a conservative timing setting or greater detonation margin on magneto or distributor controlled engines. Electronically controlled, crank triggered systems can be timed much closer to best power timing, due to their increased accuracy, provided of course that the internal components can maintain this accuracy. I do not recommend static setting of magnetos as is common with a "buzz box." Only the dynamic timing is important and this can be very different. A strobe light, as it is commonly used in the automotive industry, is an excellent way to assure accurate timing for electronic systems or magnetos. Most

One way to stop this condition is to lean the mixture past peak EGT. If there is less fuel burning there is less heat from combustion. If the mixture is rich of peak power, there is excess fuel which burns longer and shortens the cooling period between power strokes.

The cockpit display for the LSE systems allows monitoring of the automatic timing advance and the defeat of the advance to evaluate the benefit of it when compared to the standard magneto timing.

The weight savings of replacing a magneto with an electronic ignition system are insignificant, however, the available increase in efficiency can provide a significantly increased range (up to 20% can be demonstrated with the LSE CDI system) if the tanks are filled, or a lower fuel weight for a given trip. If the destination is up to 20% beyond the range of the magneto equipped aircraft, the addition of an electronic ignition can eliminate one fuel stop or provide a comfortable reserve.

Much consideration has been given to the LSE electronic ignition system's susceptibility to lightning strikes, static discharge and single event upsets. This environment is unique to aircraft and composite airplanes in particular. Critical microprocessor applications in the aerospace industry such as in space shuttle guidance computers or X31 electronic flight control systems, use three or more processors and a voting system which automatically selects the most accurate system.

As a result of investigating this potential problem, LSE decided to design discrete electronic components instead of using a much cheaper microprocessor. Using good grounding techniques and quality shielded wires for all connections, this system can be protected to a similar level as a magneto. As of today a conservatively estimated 90,000 hours have been flown in experimental aircraft using one or two LSE electronic ignition systems. There have been no reported problems from lightning strikes, static discharge, or EMI. One Glasair using one LSE CDI system and a magneto reported a lightning strike which failed two radios and a transponder without effecting the electronic ignition system.

Contrary to magnetos, electronic systems require an outside source of energy. This can be a battery or alternator system. If one ignition source is electronic and one mag is retained, no special precautions are necessary to maintain full redundancy. Both ignition sources are independent and back each other up.

When two electronic systems are used, a small designated backup battery should be installed and selectable via a switch. This battery is switched to as an emergency source of energy for one ignition system only, thus maximizing the remaining range. The use of this battery is only necessary if the alternator system (this includes belt, regulator and field switch) has failed and the main battery has been depleted. If the battery fails, it is often possible to continue until the engine is shut down. The stand-by battery should be protected against discharge with a diode and connected to the aircraft main battery in parallel. The aircraft voltmeter is connected to the center pole of the selector switch so the system voltage is monitored as usual in the normal switch position and the aux battery voltage is monitored when it is in use. As an added warning, the LSE cockpit display lights flicker when the system voltage drops below 10.5 volts, however, it remains functioning until voltage has decreased to 6.5 volts. This battery selector switch is preferred over any automatic warning/power management system, due to its simplicity and required pilot action.

Looking back at over seven years of flying with electronic ignition it becomes clear that the benefits are more significant than originally anticipated. The fuel savings alone paid for both systems by now. Additionally, valve wear is noticeably reduced, plug fouling from lead or flooding with fuel is unknown anymore. Maintenance and downtime are greatly reduced, reliability, performance and range are most significantly improved. ◆