EXHAUST SYSTEM NOTES

When I first started thinking about an exhaust system for my tri-gear RV-6A, I assumed I would buy a ready-made stainless steel crossover system similar to the one I had installed in my first RV-6 (the taildragger, that is).

That assumption, however, became a quandry after I learned that I could get a complete mild steel exhaust system for about $250 . . . this was considerably less than half the price of the stainless steel exhaust unit I originally had in mind.

Are the stainless steel stacks really that much better? Are they worth the extra cost? Maybe so. But that is not to say that a mild steel exhaust system has a short life or is inferior.

For my part, the cost of either ready-made exhaust system was still more than I had ever expended on any previous project.

Except for one donated ready-made system, all of my earlier projects were fitted with "do it yourself" exhaust stacks of one type or another.

Somewhere in my distant past, someone convinced me that if an exhaust system lasted 100 hours without failing it would go 1000 hours. I assume that profound utterance applies to the common automotive type mild steel stacks as well.

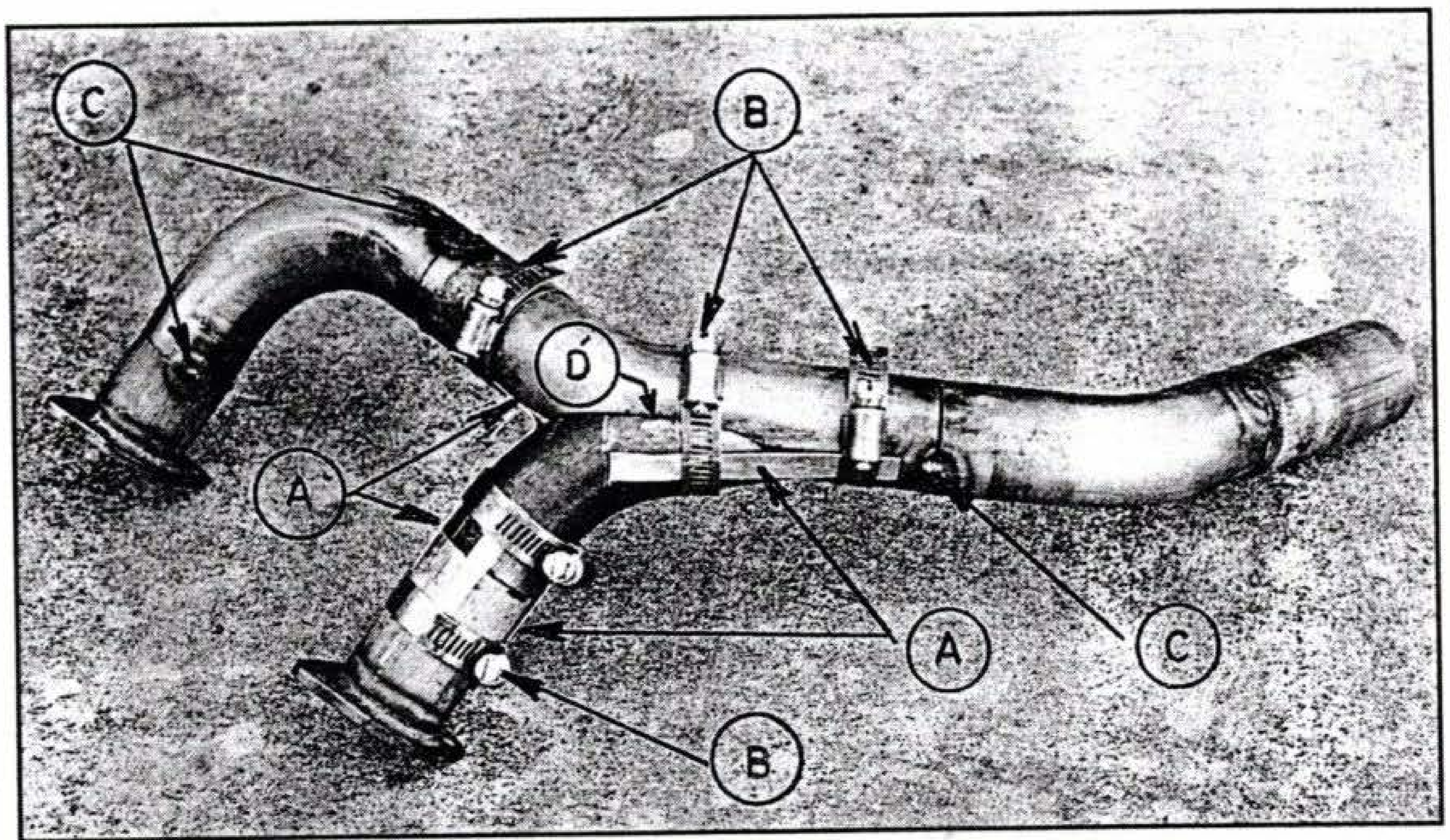
At any rate, my own experience seems to bear this out because none of my homebuilt engine installations has ever suffered an exhaust system failure. And yet, each exhaust installation was as different from the other as night is from day.

My first airplane, an Emeraude, was fitted with a brand new $28 J-3 exhaust system . . . guess how long ago that was? It never failed.

Another had a liberated Cessna 150 system complete with two used stainless steel mufflers straddling a set of used stainless stacks. It never failed.

A third was fitted with a scratch built mild steel installation using VW pipes (with lousy welds, yet). Years later, another VW installation did have better welds - but they didn't fail either.

More recently, each follow-on project was economically equipped with homemade stainless steel stacks assembled from used units purchased at fly-ins, or built up of new stainless steel exhaust flanges, straight pipe lengths and preformed elbows. No, I didn't do the welding, a friend Heliarc welded them for me (and, boy, does a builder ever need a skilled friend or two). Again, no failures.



Here's how to clamp and hold exhaust pipe sections in alignment for tack-welding. (A) Scrap metal bridging/aligning strips. (B) Stainless steel clamps. (C) Tack-welds (clamps already removed). (D) Exhaust stack joints to be welded.

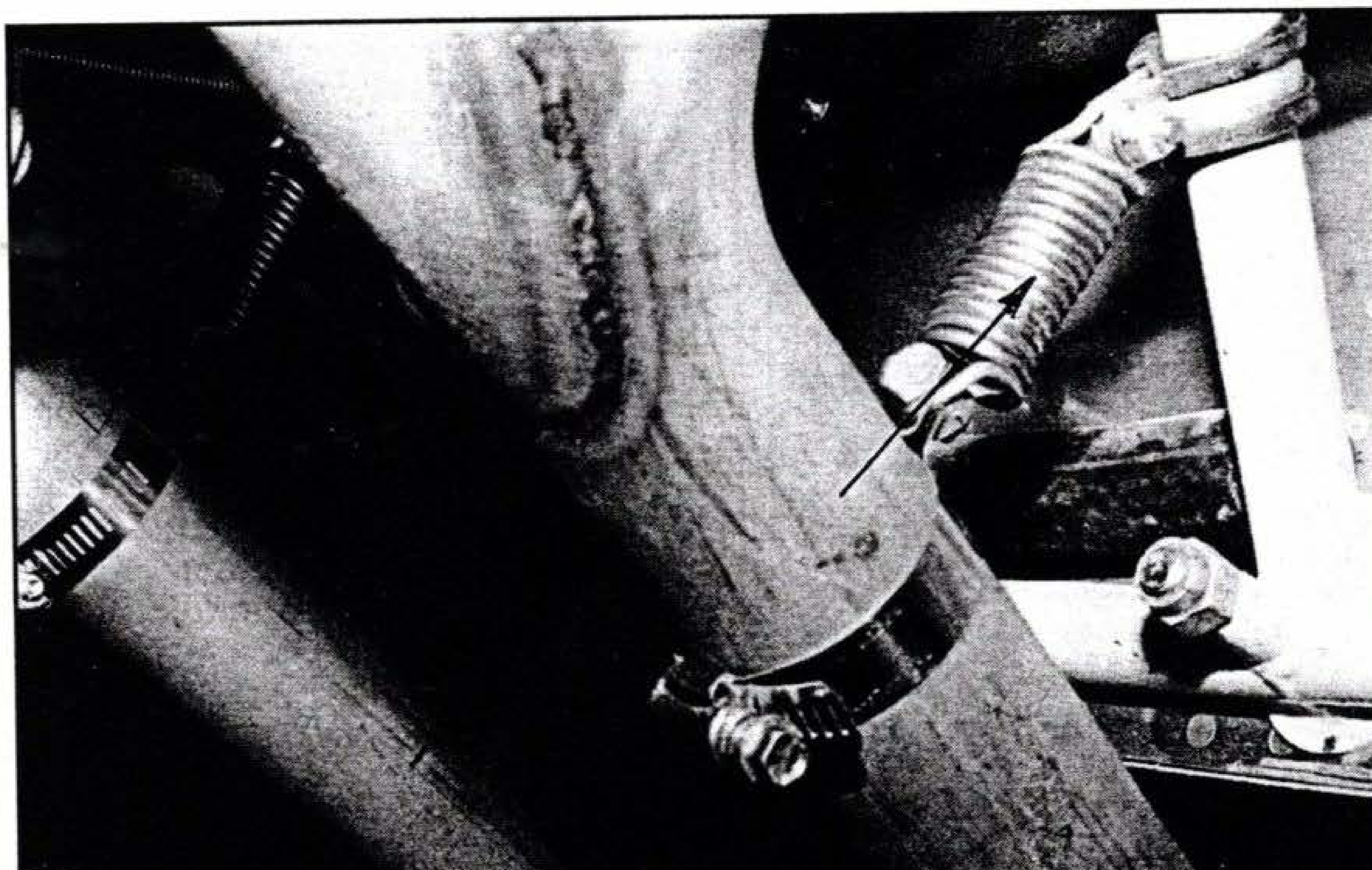
For the life of me I don't know why some of my earlier installations remained trouble-free for the several hundred hours each of them was flown. A little luck, perhaps, and plenty of well located expansion (slip) joints, and properly supported tail pipes, I guess.

Since I have never experienced a failure in either the ready-made or homemade exhaust systems (mild steel or stainless) I have use, I have no preconceived preference for one type of metal over the other.

I do consider myself fortunate that I no longer have to build my own exhaust system and can, if I prefer, purchase a ready-made set from any one of several reliable sources.

A number of these ready-made exhaust systems are designed and custom-fabricated to fit specific aircraft designs - designs like the RV's, T-18's and Mustangs to name a few.

Incidentally, the newsletters, subscribed to by builders for their particular aircraft, are often good information sources for various


Bracing exhaust pipes against the engine mount or fuselage structure is a poor practice because the engine moves in its shock mounts and the fuselage does not. Result, failed pipes. As shown here the spring may minimize the problem.

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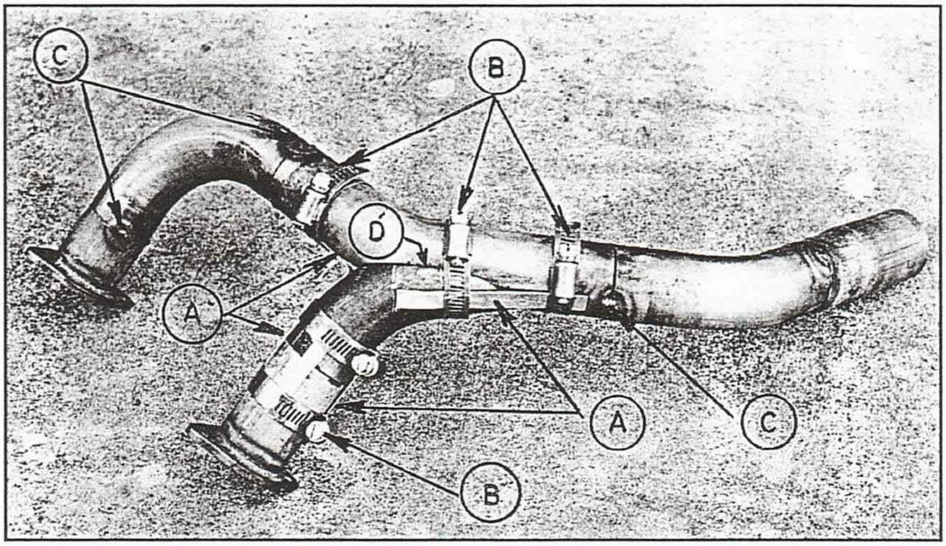

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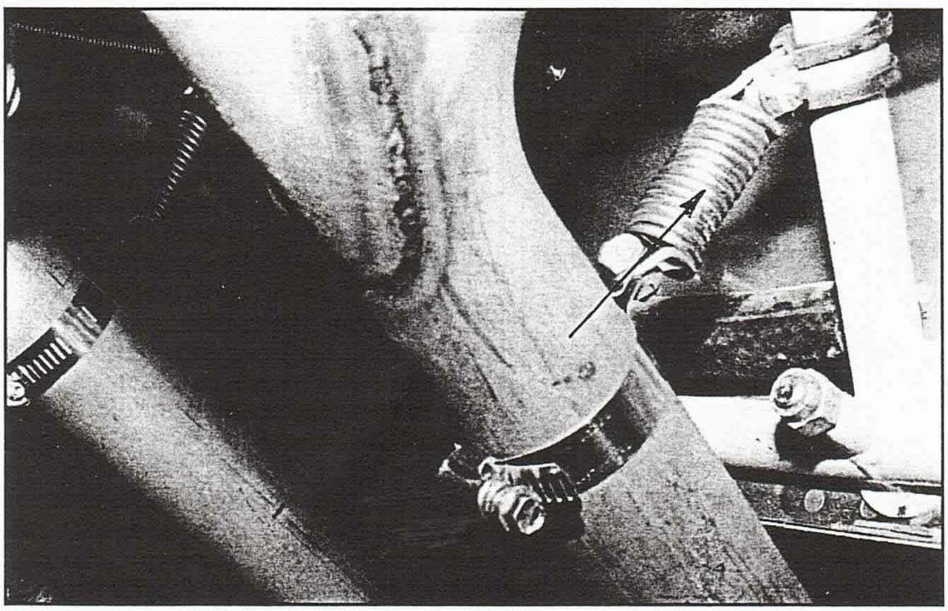

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IGNITION BATTERY MANAGER

Reliable Aircraft Operations With Battery Powered Ignition Systems

By BOB NUCKOLLS
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6936 Bainbridge Rd.
Wichita, KS 67226-1008

I met many people at Oshkosh this year who believe magnetos should go the way of buggy whips and vacuum tubes. Major concerns for everyone contemplating dual electronic ignition was (1) redundant power sources and (2) pilot notification. The "black box" addressing these concerns does not yet exist although it could in a short period of time. The purpose of this article is to (1) solicit peer review of the concept and (2) put a dipstick into the pool of builder enthusiasm. Look this over carefully, folks, and see if it makes sense.

Introduction

In recent years, new electronic ignition systems designs have partially or even totally replaced magnetos on aircraft engines. Battery powered systems have many advantages over magnetos which include:

1. Increased spark energy during engine cranking.
2. Higher energy and/or long duration sparks for cruising flight (necessary for high efficiency, lean mixture operations).
3. Engine efficiency improved in cruising flight by application of maximum advance of timing consistent with operating conditions.
4. Battery powered ignition systems can take advantage of relatively cheap, but reliable automotive components. Costs are approaching that of magnetos. Repairs by users are simpler. Many repair parts are available from multiple sources.

Significant challenges for incorporation of battery powered ignition systems on aircraft are revealed by failure mode effects analysis (FMEA). The tasks are (1) to design a system wherein no single component failure will disable both ignition systems and (2) ensure ignition system operation (irrespective of alternator condition), allowing comfortable termination of flight. The following will describe hardware and a design philosophy to address both tasks.

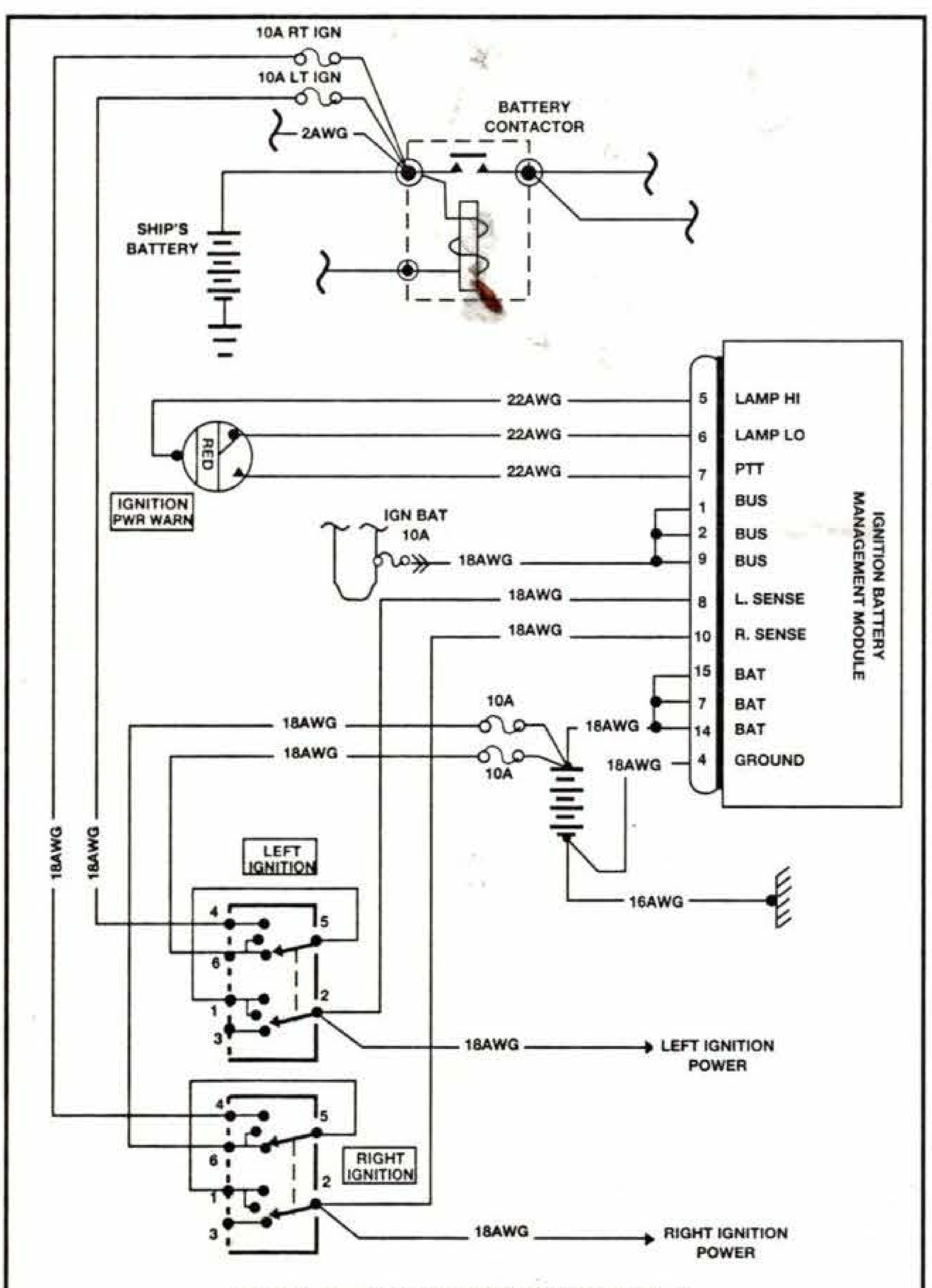


FIGURE 1. IBMM POWER DISTRIBUTION

Major Components

The proposed system is compatible with most battery powered ignition products. The only limitation being that proposed ignition systems should not be more than 5 amps each in cruising flight. Figure 1 illustrates application of a proposed Ignition Battery Management Module (IBMM) and Auxiliary Ignition Battery. Major components of the system are:

Ignition Switches

Power to each ignition system is controlled by a three-position toggle switch. The lower extreme position is OFF which removes power from the respective ignition system. In the middle AUX position power is supplied from an auxiliary ignition battery. The upper ON position feeds the system from the ship's main battery.

Auxiliary Ignition Battery

An auxiliary battery is included to provide a second source of ignition power in addition to the ship's normal d.c. power system. This battery is sized in consideration of d.c. power requirements for each ignition system and the maximum anticipated operating time under failed alternator conditions.

Ignition Battery Management Module (IBMM)

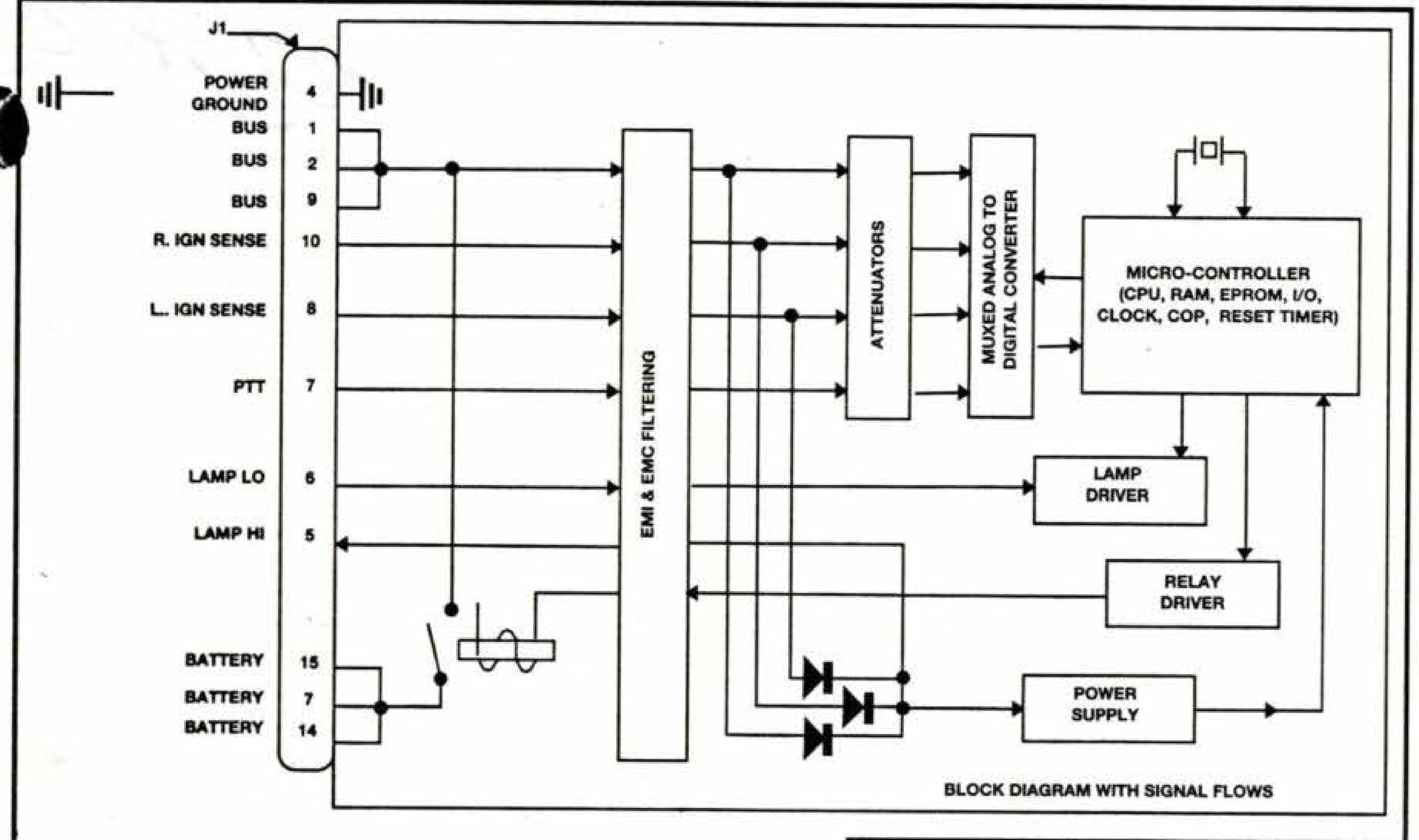
The ignition battery management module is a microprocessor based voltage monitor and warning device which includes an auxiliary battery isolation relay. The device would be about 2.5 by 4.0 by 1.0 inches in size and weigh about 0.4 pounds. The IBMM simultaneously monitors voltages at three different points: (1) the ship's power distribution bus, (2) the voltage applied to the right ignition system and (3) voltage applied to the left ignition system. The IBMM automatically controls an auxiliary battery disconnect relay and develops pilot warnings as follows:

a. Bus voltage is monitored for the purpose of controlling the auxiliary battery isolation relay. For bus voltage greater than 13.0 volts, the alternator is assumed to be operating normally and the isolation relay is held closed. This provides (1) a charging path for the auxiliary battery during normal operations and (2) an alternate path for power to either ignition system.

b. Voltage applied to each ignition system is monitored to provide warning of incipient battery failure during battery-only operations.

The IBMM drives a press-to-test, dimmable indicator lamp assembly which operates in the following manner:

a. When system power is first applied, the IBMM's processor accomplishes an internal self test. Upon successful completion of test, the light will illuminate for 3 seconds and go dark. Immediately following the self



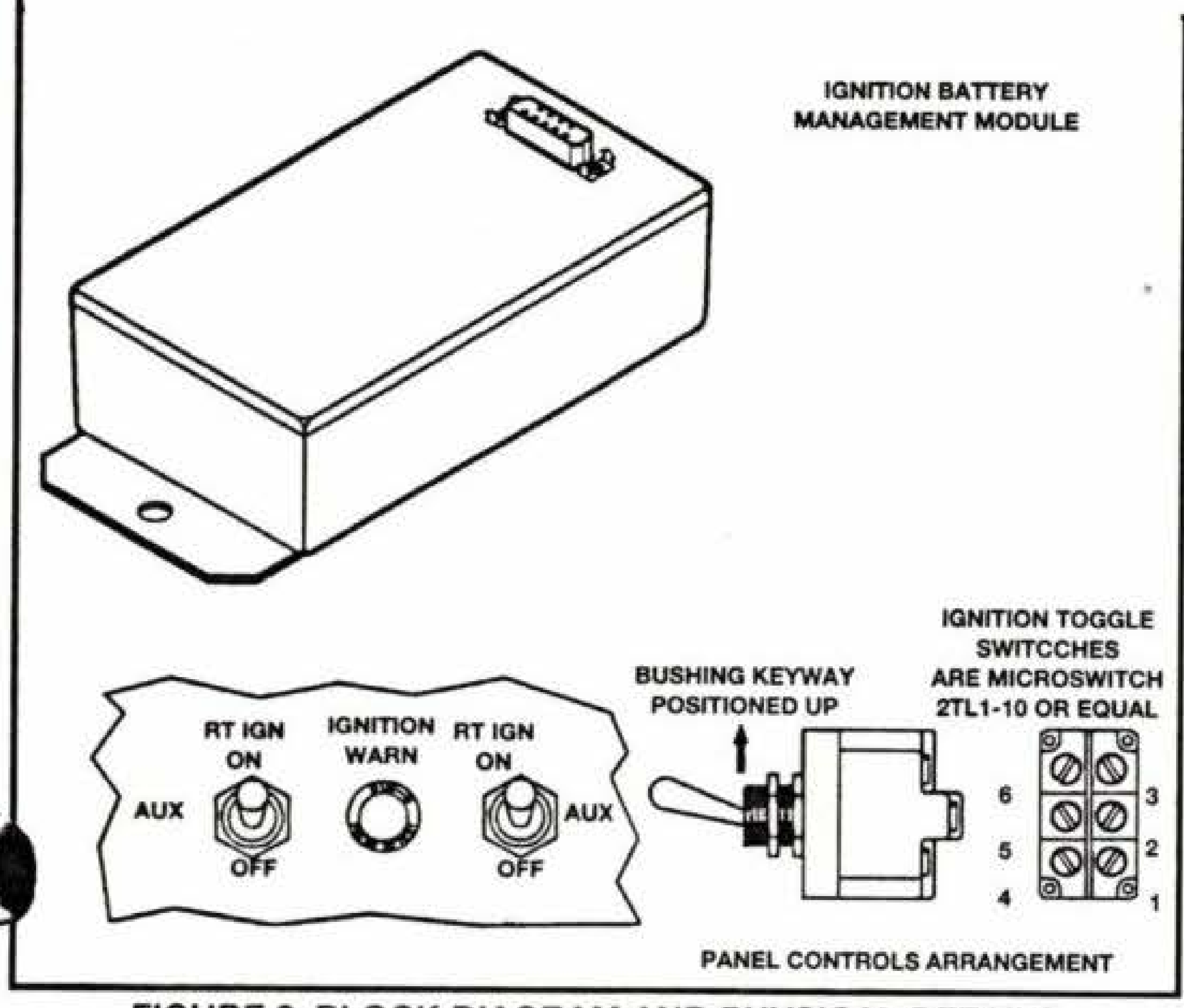


FIGURE 2. BLOCK DIAGRAM AND PHYSICAL DETAILS

test, if both ignition system supply voltages are greater than 13.0 volts, the light will stay dark. If either system supply voltage is between 11.0 and 13.0 volts the lamp will display short double flashes at 1 second intervals. If either voltage drops below 11.0 volts, the lamp will flash continuously with a uniform on/off duty cycle.

b. Pressing the light fixture dome initiates a self test which will illuminate the lamp for 3 seconds followed by a suppression of any current warnings for a period of five minutes. After five minutes, if normal alternator operations have not been restored, the light will again resume flashing the current worst-case warning as described above. Pressing the fixture will initiate warning suppression for an additional five minute interval.

c. For normal operations with alternator producing power, the indicator light will be dark. During this time, the battery isolation relay will be closed for ignition battery charging. Either or both ignition systems may receive power through the battery charging path by placing their respective control switch in the AUX position.

d. If the alternator fails to maintain system voltage above 13.0 volts, the warning light will display an intermittent double flash to alert the pilot of alternator failure. Simultaneously, the auxiliary battery isolation relay opens to prevent ship's electrical system loads from discharging the auxiliary ignition battery. If the alternator operations are recovered, the warning will cease and the isolation relay will re-close. If the alternator cannot be brought back on, the warning can be suppressed for 5 minutes by pressing the light fixture.

e. If either ignition system supply voltage falls below 11.0 volts, the warning light will initiate continuous flashing. Ignition switches may be adjusted to transfer the system receiving low voltage to a higher voltage source. Or, at pilot option, the ignition battery may be conserved by leaving one ignition feed connected to the "failing" battery. Imminent battery failure warnings may be suppressed for 5 minutes by pressing the light fixture.

Preflight Operations

1. Battery Master - ON
2. Alternator Field - OFF
3. Both ignition switches - AUX (IBMM indicator light illuminates for 3 seconds then initiates double-flash indication.)
4. Prime engine and crank. After engine starts . . .
5. Alternator Field - ON (IBMM indicator light goes out.)
6. Left ignition swith - ON
7. Right ignition switch - leave on AUX
8. Complete engine run-up with usual mag checks then continue normal flight operations with one ignition switch at ON; the other at AUX.

Alternator Failure

1. IBMM indicator light initiates double-flash indication. No system management actions by pilot are needed. Warning indication may be suppressed for 5 minutes by pressing the light fixture.

2. If during alternator-out operations the IBMM ndicator light displays a steady flashing, observe ship's voltmeter to determine whether the ship's battery or auxiliary ignition battery has discharged below 11.0 volts.

a. If ship's battery is still above 11.0 volts, place both ignition switches in the ON position.

b. If ship's battery is below 11.0 volts, pilot has option of switching both ignition systems to AUX or loading the ignition battery with only one system to maximize flight time on available battery power.

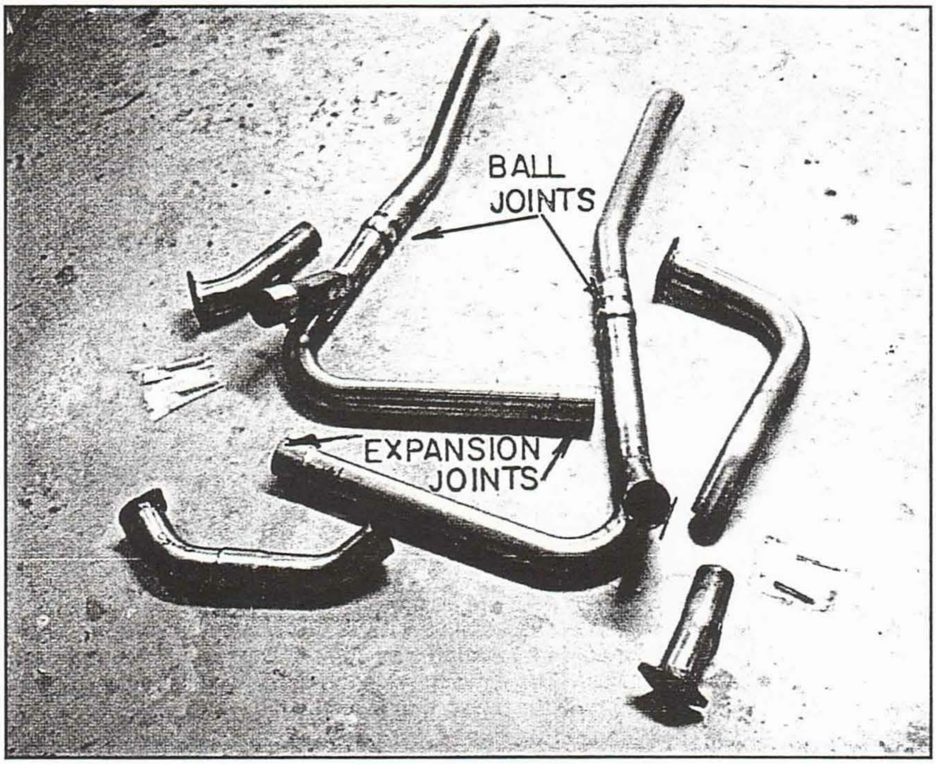
Summary

The proposed system permits dual battery powered ignition systems to operate normally from the ship's main power distribution system with automatic changeover for one ignition system to the auxiliary battery in case of a catastrophic failure of main power. Two independent batteries are charged from a single alternator, however, the second battery is automatically protected from premature discharge by back-flow of energy into a failed ship's system. The pilot is offered immediate notification of change of status for critical system supply voltages. Power switching for both ignition systems is accomplished through simple switches and minimum-component pathways to each battery.

A detailed failure mode effects analysis of this system indicates that no single failure will cause loss of engine ignition power. Redundancy is achieved without a second alternator and adds approximately 6 pounds to the electrical system weight.

Bibliography

The author may be contacted directly at 316/685-8617 or Compuserve 72770,552. Written coverage and real-time consulting services on this and other electrical systems topics are available from the AeroElectric Connection, 6936 Bainbridge Rd., Wichita, KS 67226-1008. $42 USD buys all materials in print (13 chapters, lots of illustrations, 5 appendices, 200+ pages) plus one year's subscription to newsletters and the next issue of chapters on specific topics. Overseas subscribers add $20 USD for airmail postage. MasterCard and Visa are accepted. ◆



This ready-made exhaust system design has a generous number of expansion joints as well as two integral ball joints for the tail pipes.

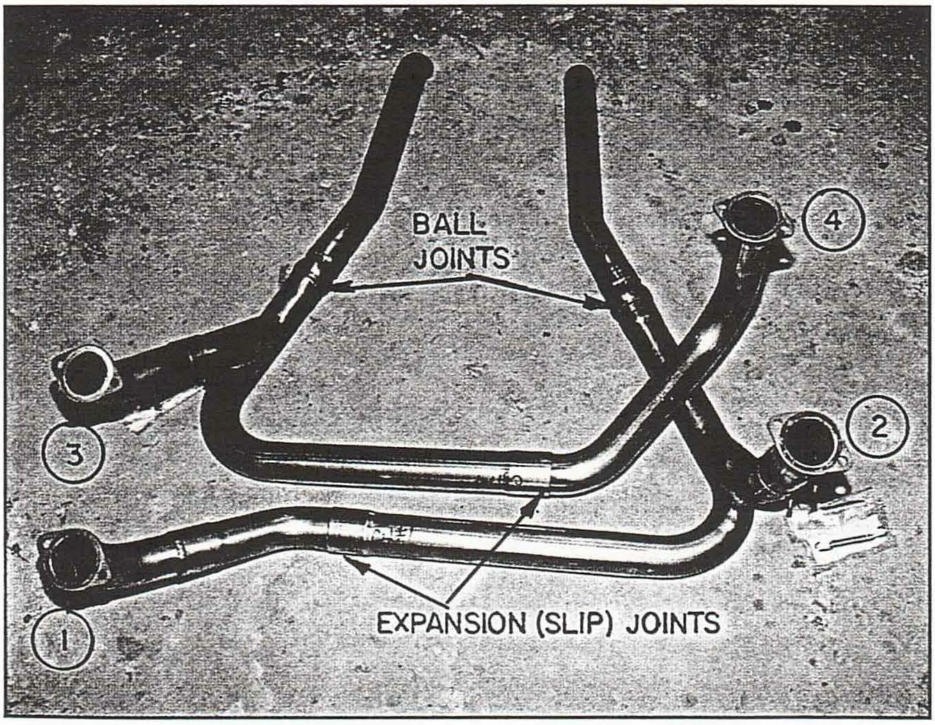
component parts - including complete exhaust systems.

Naturally, if you prefer, you can still fabricate your own exhaust system using parts available from one of the homebuilder suppliers, or from some local muffler shop.

But, before you can buy a complete system or build your own, you must first decide whether you want to have those expensive stainless steel stacks - or the less expensive mild steel variety.

Mild Steel vs Stainless Steel Exhause Systems

Anyway, what difference does it make if you install a mild steel exhaust system instead of a stainless steel system? Your engine won't know the difference. Your pocketbook will though.



A Bird's eye view of a typical crossover exhaust system. This one uses mild steel automotive pipes. Note that the two front cylinders are interconnected and that the exhaust gases exit through the left tail pipe. The two rear cylinders are also interconnected and exhaust gases exit through the right tail pipe.

I am sure you are aware that the mild steel exhaust pipe installations in automobiles are reliable and hold up very well.

Of course, the prevailing belief among many homebuilders is that mild steel pipes, especially in infrequently flown homebuilt aircraft, are bound to suffer more rust than even those seen in the most abused and neglected cars.

Although the mild steel exhaust pipes will pick up a film of surface rust almost immediately, the assumption that destructive corrosion is quick to follow is not a valid conclusion.

A local VariEze has been flying for years with a mild steel exhaust system that was originally installed eleven years ago. How about that?

I know of stainless steel installations that didn't last half as long . . . they often burned out in and around the mufflers, or suffered cracked exhaust flanges.

Well, now, if rusty pipes offend your senses, you could:

1. Paint the pipes with a high temperature (2,000 degree F., preferably) automotive header paint. Properly done, this high temperature paint is quite effective and will enhance the appearance and prolong the useful life of your automotive pipe exhaust system for many years. Follow the painting instructions carefully. This is the least expensive and most commonly used treatment for protecting mild steel stacks against rust.
2. Have the mild steel pipes coated with Jet-Hot, a relatively new high-temperature coating for exhaust systems.
3. Have the stacks aluminized.
4. Have the exhaust system chromed.

Sometimes there can be an unexpected advantage to using a mild steel exhaust pipe installation.

For example, in the event you do develop a broken pipe on a cross-country flight, the chances of getting the mild steel pipe welded most anywhere are a lot better than trying to find someone who can repair and reweld stainless exhaust pipes.

A word of caution. Some coated mild steel exhaust pipes may be difficult to repair. Aluminized pipes are probably the worst in this respect. That is, they cannot be reliably re-welded.

It is true. A mild steel exhaust system will be heavier than a similar stainless steel system because the automotive pipes have a heavier

(.050") wall thickness. In contrast, stainless steel pipes have a thinner .035" wall thickness. Even so, my ready-made (Vetterman) mild steel crossover exhaust system in the RV-6A weighs only 12 pounds.

The price difference between a mild steel exhaust system and that of a stainless steel system, on the other hand, is considerably greater than the modest weight difference.

That dollar difference alone can make the automotive pipe exhaust system quite irresistible to a budget minded builder - whether he buys or builds his own.

If You Have To Builder Your Own

If you can buy a ready made exhaust system designed for your aircraft type, I would recommend you get it rather than to try to build your own . . . it might be cheaper in the long run.

There is more to fitting and developing an exhaust system than merely routing the exhaust gases from each cylinder overboard.

John Thorp, designer of the fabulous T-18, used to say that a well designed crossover exhaust system could net a 10% increase in power. However, that may not be true compared to the semi-tuned four pipe exhaust system I bought from Larry Vetterman. It could be true, though, when you compare a crossover system efficiency with that of a common two pipe "Y" branch installation.

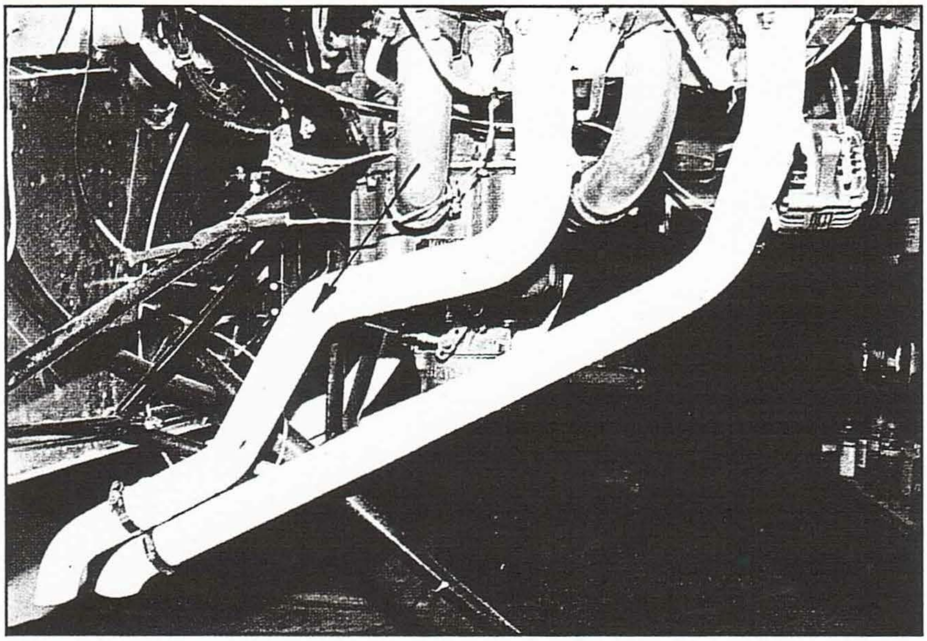
When building your own exhaust system, you should realize that if it is improperly done, your exhaust system could suffer from unnecessary power losses due to abnormal back pressures in the system. The installation might even fail after a few hours due to the lack of properly located expansion joints.

What kind of exhaust system would you build? A crossover system? A semi-tuned four pipe exhaust system? Maybe a simple exhaust installation with four short straight stacks? They all work.

However, unless you have the technical background for that sort of thing I would suggest doing it the easy way - duplicate one of the exhaust installations in use in some recent vintage store-bought aircraft.

Making Your Own Exhaust System

If you are a careful buyer, or a good scrounger, you can effect significant savings by building your own mild steel exhaust system . . . especially if you can do a creditable job of gas welding the mild steel pipes.



This mild steel four pipe exhaust installation was painted with a high temperature paint as protection against rust. The extra bend in the upper stack would indicate that an attempt was made to tune the pipes, that is, make the lengths equal.

Attempting to weld your own stainless steel exhaust system, on the other hand, may not be as rewarding as it requires special welding techniques, more know-how, and perhaps, some expensive welding equipment.

Although most commercially produced aircraft use expensive mufflers, you will probably fabricate your exhaust system without them to simplify the installation and reduce cost and weight.

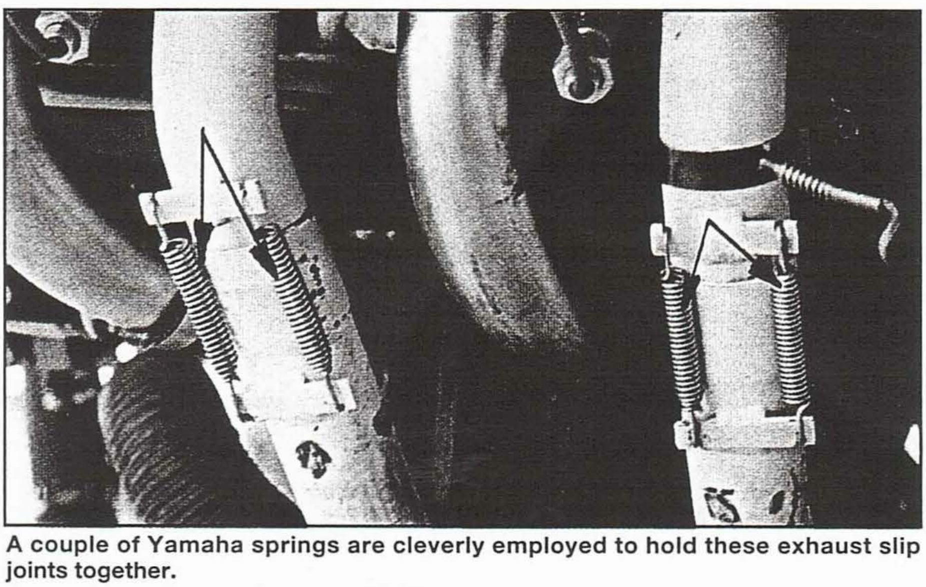
The argument made for eliminating mufflers is based on the premise that they are heavy and that homebuilts have very tight fitting cowlings with almost no extra space for mufflers. (Those excuses, incidentally, don't hold water in Switzerland and in other environmentally sensitive countries.)

1. Begin fabricating your exhaust system by making your own mild steel exhaust flanges - or you can simplify the job by purchasing a set to fit your engine (Lycoming or Continental).

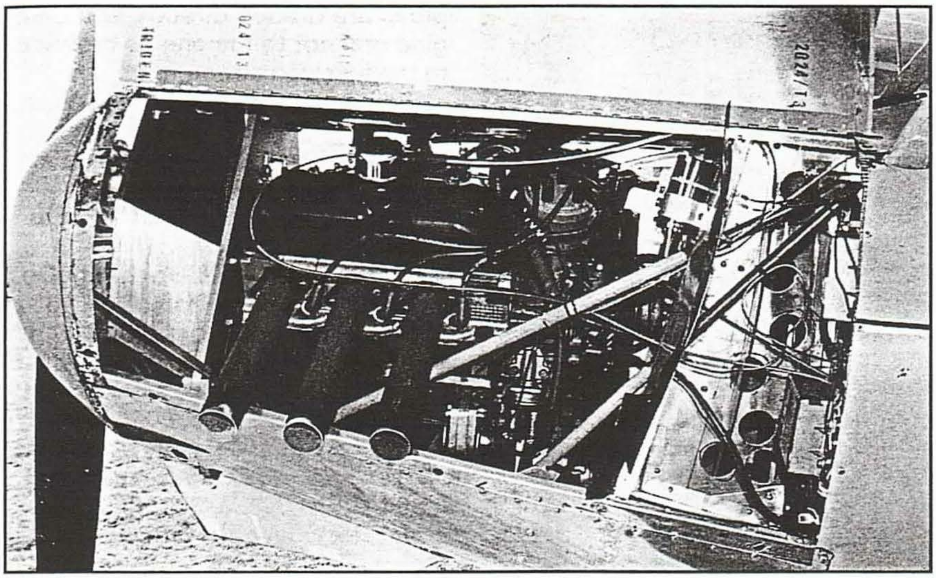
2. Start to assemble the component parts by welding the exhaust flanges to short pipe sections about 4"-6" long. Use 1-3/4" dia. pipes for a Lycoming, and a 1-1/2" dia. for most Continentals.

3. Next, temporarily bolt the prewelded exhaust stack stubs to each cylinder. This will establish the correct exhaust flange alignment for each cylinder and will accurately position the stub stacks. The other exhaust system pipes can then be fitted and clamped to these stubs.

4. Decide where to locate the slip



A couple of Yamaha springs are cleverly employed to hold these exhaust slip joints together.



Short straight stacks are easy to make but they are noisy and may allow engine to cool excessively during letdowns.

joints and ball joints for a trouble-free exhaust system.

5. Cut, fit and clamp each pipe section together.

NOTE - If you think that figuring out how to fit and hold the various pipe sections in place while attempting to assemble and tack weld your exhaust can be difficult, you're right. It is no simple undertaking. The easiest way to do this is illustrated in one of the photos. Notice how the separate pipe sections are clamped together with small metal strips and steel hose clamps to form the assembly. This steel clamp jigging technique is especially effective when you have to work alone.

6. After all of the pipe joints have been immobilized with the steel clamps, remove the assembly from the engine and tack weld the joints.

7. After tack welding, reinstall the pipe assemblies on the engine to double check the routing and clearances. Then you can take the tack welded exhaust stacks to your favorite welder and have the welds completed . . . either that or do it yourself.

NOTE - Do not buy or use curved automotive pipe sections that have a rippled or buckled inside radius. You should be able to purchase smoothly bent exhaust pipe sections at most any muffler shop.

You might, on the other hand, find a local shop equipped with mandrels that does custom bending of pipes for hot rodders and the automotive set. This would permit you greater flexibility in obtaining the exact bend radiuses you need in your pipes.

Such a shop can also expand the diameter of one end of a pipe so that it will form a slip joint when assembled with another section of pipe.

Avoiding Exhaust System Failures

Exhaust systems deteriorate and fail because of high engine operating temperatures, vibration that causes metal fatigue in stress concentrated areas, and wear at joints and in clamped connections.

A number of our local area homebuilts have suffered exhaust system problems over the past few years. These problems are quite typical and included cracked exhaust flanges, burned and cracked stacks, and broken tail pipes as well.

Most of the cracks were detected in the welded areas of the exhaust flanges. However, a couple of the aircraft did have exhaust pipes break off completely in flight. Fortunately, no engine compartment fires occurred.

Most of the affected homebuilt owners attributed the failures to the relatively thin walled stainless steel pipe used, and to improper welding technique. Not all the problems were limited to stainless steel exhaust systems.

For my part, however, I believe almost all of the failures in homebuilt exhaust systems can be traced to improperly supported tail pipes.

Sometimes, inexplicably, what appears to be an adequately braced installation does develop a crack, or breaks off completely.

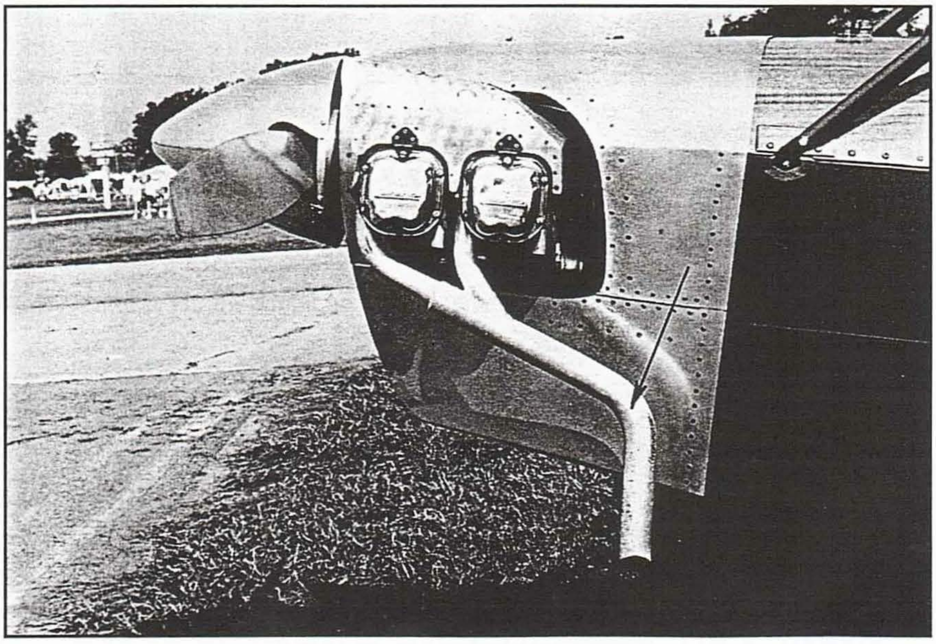
In those instances one can only assume that the design and fabrication of the exhaust system didn't provide for properly located expansion joints, and flexible joints that would have allowed the exhaust pipes to expand and contract during normal engine operations.

It is obvious that exhaust system problems are aggravated because they operate under some pretty severe conditions.

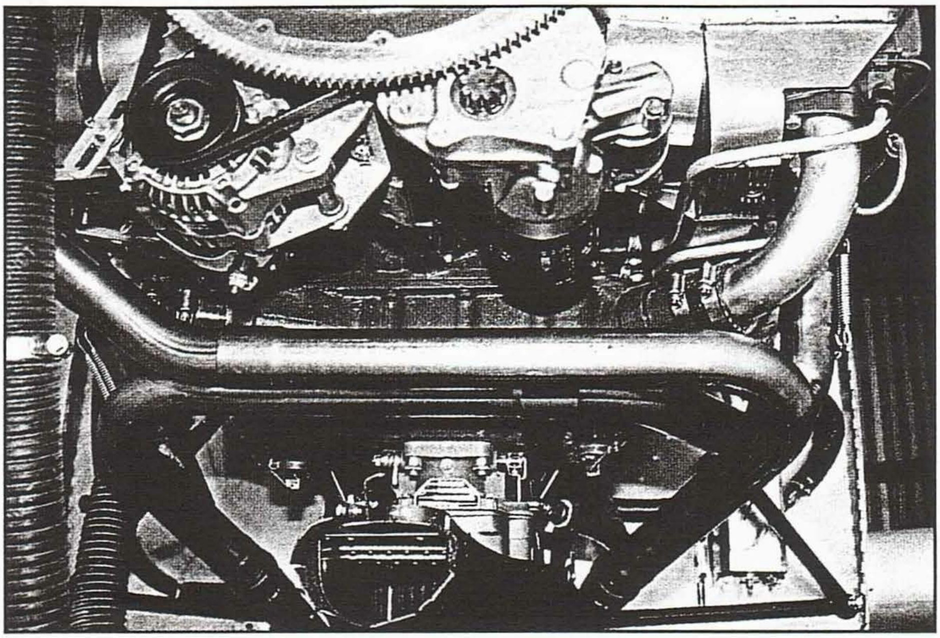
For example, the exhaust gases exiting the engine are so hot they heat the pipes red hot . . . about 1400 to 1600 degrees F.

Further downstream, the temperatures are significantly lower causing an uneven heating and expansion along the length of the pipes.

To make matters worse, a sudden cooling of the exhaust pipes caused by prolonged power off letdowns can add still more abuse to the welded joints, and to the entire exhaust system.



How long do you suppose this exhaust system will last without some sort of support for that long heavy tail pipe?



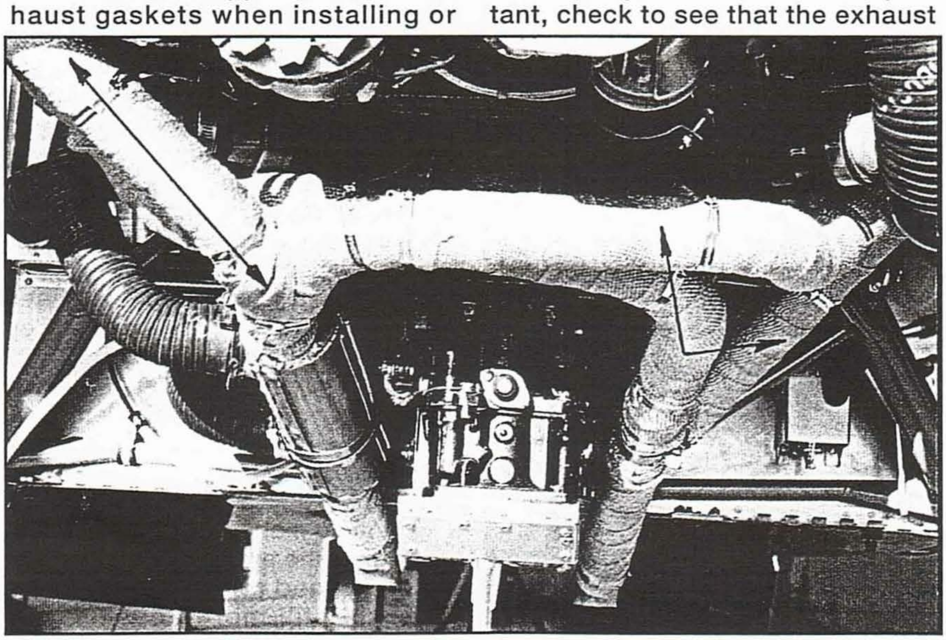
In a crossover exhaust system, both pipes cross in front of the engine crankcase. The close proximity of the hot pipes might influence the engine oil temperature. If that is a problem, the installation of a heat shield between the closest pipe and the crankcase should be considered.

I don't recommend wrapping exhaust pipes with one of those automotive "Exhaust Insulating Wrap" kits regardless of the claims made for them. A local Mustang II equipped with a mild steel exhaust system suffered complete failure of the pipes in all of the bend areas. His thermal wrapped pipes had completely burned through.

Do remove your cowling at frequent intervals and carefully inspect the entire exhaust system - inch by inch.

Here are a few things to look for:

1. Exhaust leaks and cracks. These areas usually show up as gray-white streaks.
2. Use new copper/asbestos exhaust gaskets when installing or replacing your exhaust system. Do not reuse the old gaskets.
3. After the first 10 hours of flying time, re-torque the exhaust flange nuts. Be sure you have a plain steel washer and a new star lock washer under each nut.
4. Look for loose or broken clamps and connectors.
5. Check to see that stacks are not dented.
6. Look for cracked or broken stacks and tail pipes.
7. Check heat muffs (and mufflers, if installed) for condition and broken connectors.
8. Be sure the SCAT ducting is in good condition.
9. Finally, and this is most important, check to see that the exhaust pipes are braced directly to the engine and not to the engine mount or to the fuselage structure.



Wrapping the exhaust pipes in aircraft may be a bad idea. Local experience would indicate that burned/failed stacks could result.

Remember this . . . the best place to cope with exhaust system problems is on the ground, not in the air!

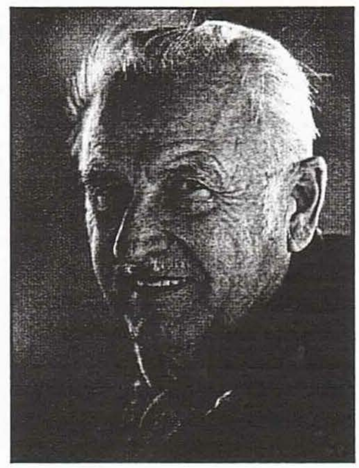
A Few Exhaust Systems Sources

Aircraft Spruce & Specialty Co., PO Box 424, Fullerton, CA 92632, 1-800/824-1930 (for ordering).

Alan Tolle's Custom Aircraft Components, 2920 Staunton Ct., Bakersfield, CA 93306, 805/871-4144.

High Country Exhausts, Larry Vetterman, 7216 S. Pierce Ct., Littleton, CO 80123, 303/932-0561.

Jet Hot Coatings. Three U.S.A. locations offering 72 hr. turnaround time. 1-800/432-3379 (toll free info).



If you wish to contact the author of this column for additional information, please send a SASE to Tony Bingelis, 8509 Greenflint Ln., Austin, TX 78759.