SECTION 15. FINAL INSPECTION AND FLIGHT TEST

In the life of every homebuilder there comes the day when his airplane is finished and ready to fly.

Or is it?

For some builders the process has been long, sometimes several years. We learn from experience and we pass that learning along to our builders as needed. Before you undertake the test flying of your new airplane, check for **"Service Bulletins"** on our web site at www.vansaircraft.com. It is in your best interest to check this web site periodically to keep up with the latest improvements in your aircraft.

A reported 20% to 30% of homebuilt aircraft fatal accidents occur within the flight test phase (first 25-40 hrs.). Flight test statistics for RVs are far safer than this. However, these sobering statistics should provide the incentive to undertake flight testing in the most professional manner possible. Because the majority of accidents, perhaps 80-90%, result from pilot error, pilot "airworthiness" should be of paramount concern.

The last steps in building an airplane are a very thorough final inspection of both the pilot and the aircraft to assure that everything possible has been done to make it airworthy, followed by a carefully planned and organized flight test program to verify that the airplane not only flies, but meets all performance, stability, and handling goals.

One who builds a homebuilt airplane is known as an "amateur builder". However, we don't often use the term "amateur test pilot" to define his role during the flight testing of an airplane. In reality, the typical private pilot is terribly under-qualified to serve as a test pilot, at least when contrasted to the training and qualification of professional test pilots. Fortunately, the flight testing of many ABE (Amateur Built Experimental) aircraft consists of little more than a self help check out in a new airplane. Aircraft of proven design (such as the RVs), which have been accurately built from high quality kits, usually pose few challenges to their test pilots, even in the early hours of flight. However, this ideal cannot be guaranteed and no assumptions of unquestionable airworthiness should be made. A "test" pilot must be prepared for any irregularity which may occur.

The goal of this chapter is to help you do flight test planning and flight testing in a way that eliminates the need for you to demonstrate that you have the "right stuff". When it comes to flight testing, boredom beats excitement. This chapter will also help you gain a better knowledge of the fine points of the performance, stability, and handling qualities of your airplane. Put another way, we will try to teach you some of the things which test pilots need to know.

Using the first flight of your RV as the central point, we can consider two basic phases of testing: Pre-First Flight and Post First Flight.

PRE FIRST FLIGHT

Pre-First Flight activities include two main topics; inspection and preparation of the aircraft, and inspection and preparation of the pilot. Everyone agrees that the aircraft should be thoroughly checked over and made airworthy, but not everyone is as concerned about the airmanship of the pilot, particularly the pilot himself. They should be. After the first flight is completed, subsequent flights can be dedicated to increasing the proficiency of the pilot, improving his or her connection to the airplane, and exploring the performance and limits of the airplane itself.

The following sequence of inspection, preparation and flight test procedures has been compiled from a series of flight test articles authored by Tony Bingelis in the Jan-Mar. 1989 issues of *Sport Aviation,* a 1989 FAA Advisory Circular titled *Amateur-built Aircraft Flight Testing Handbook*, and insights from RV designer Richard VanGrunsven. Another more in depth and very valuable book is *Flight Testing Homebuilt Aircraft* by Vaughn Askew, published by the Iowa State University Press, and also available from Van's Aircraft.

INSPECTION AND PREPARATION OF THE AIRFRAME

Weight and Balance: Go over your figures one more time. How will the airplane be loaded for test flight? Will it be under gross? Don't fly the airplane with an aft CG condition. If necessary, add ballast and fasten it securely. Be sure the ballast will not interfere with the controls, or chafe on installed wiring and fuel lines. Carry plenty of fuel for the first flight, but limit it to no more than half your fuel supply.

Landing Gear: For RV-8 builders, assure compliance with the wheel alignment specification presented in Section 10 of this manual. If a tailwheel is installed, examine it to see that its pivot axis is vertical, or, preferably, slopes back slightly (trails.) Difficult runway handling often results when the tail wheel pivot axis is raked forward and the tire contacts the ground ahead of the imaginary projected pivot axis.

Be sure the linkage and springs on a steerable tailwheel are correctly tensioned. There should be between 1/4" and 1/2" sag in the chain/cable assembly.

Brake System: Check for positive pressure at the brake pedals. Both should have similar feel; a firm resistance after about 1/2" of pedal travel. The pressure should hold as long the foot pressure is held on the pedal. While holding the brakes, have someone try to push or pull the plane to make sure that the brakes are working. "Soft" pedals usually indicate the presence of air in the brake lines, require the system to be purged. Pedals that "bleed" down and need to be "pumped" up often indicate a fluid leak in the lines, master cylinder, or brake cylinder itself.

Flap Operation: Check the flap system through its full travel for freedom of movement. On manual flaps, have someone apply lifting pressure to the flap itself while you operate the flap handle to make sure the latch mechanism holds and releases as it should. Check to assure that the flap handle and/or flaps have travel limits and cannot be extended beyond the maximum intended position, causing an over-center binding.

Flight Controls: Your control system is vital to safe flight and requires very close scrutiny. Operate the rudder, elevator, and aileron controls through their full travel. Assure yourself that ALL the controls are connected, secured and safetied -- and that they all operate freely and smoothly and in the correct direction. No play should be permitted in the control hinges; sloppiness may induce flutter. Likewise the trim tabs must be free of excessive play. Review the control travel limits.

Fuel System: Check your fuel selector valve. Perform tests to assure that the tank indicated is actually feeding, and that the "off" position does stop the fuel flow. It must function easily with a definite click in each tank position. Verify that the engine will run in each tank position (except OFF, of course.) Smell fuel in the cockpit? Check the connections for each fuel line. A fuel leak cannot be tolerated.

Design Travel in degrees	***Maximum Up/Down***	***Minimum Up/Down***
Elevator	30/25	25/20
Aileron	32/17	25/15
Rudder	35/35 l/r	30/30 l/r
Flaps	40–45	(32–37 RV-9/9A)
Trim Tab	25–35	

Are your vent lines open (are you sure?) and properly exited outside the aircraft? Protect the vent openings with aluminum screen to keep the bugs out.

Propeller: Re-torque and re-safety the propeller bolts -- especially if a wood prop is installed. Recheck the track of the propeller to make sure the blades are rotating in the same plane. An easy procedure that should take about thirty minutes is shown in Section 12.

An out-of-track propeller condition can be corrected by placing a paper shim between the rear face of the prop and the mounting flange, on the side with the trailing tip. Common typing or copier paper can be used for the shim,. By loosening the prop bolts, a paper shim can be slipped in and the bolts re-torqued with a minimum effort. A single sheet thickness of copier paper is equal to a tip correction of about 1/16". After shimming, re-check for track. Repeat this process until the prop blades track within 1/16".

Propeller Shaft Extension Alignment: A less common but more serious problem than prop tracking is that of crankshaft prop flange misalignment. If the crankshaft flange is bent slightly, it would cause an out-of-track prop condition, if a prop were bolted directly to it without an extension. When a shaft extension is used, the prop becomes not only out of track, but off center as well. If this condition goes undetected, a serious vibration (out-of-balance)condition can result, even though the prop is balanced and in track.

Checking for an out-of-alignment flange and prop shaft extension is done with a dial indicator. Aircraft mechanics and machinists are familiar with this tool, and can probably help you with this test.

The dial indicator mounting stand (shaft) must be clamped to the engine and positioned so that its sensor tip is in contact with the front flange of the prop extension. Rotating the prop through 360 degrees will indicate an out of line condition. The prop extension can be shimmed straight using the same technique as for prop tracking.

Engine Controls: Verify direction of movement and security of attachment at the engine. This means somebody needs to check the movement at the carburetor -- takes two people to do it. Beware of possible spring-back or inadvertent locking in the linkage when any engine control is moved to its extreme position.

Checklists and placards: No excuses, you need them. Review them for accuracy, completeness, and ready access.

One pre-takeoff check list that is easy to remember is based on the letters in the word C I G A R E T T E. They stand for:

- **Controls:** Move and visually check for proper operation.
- **Instruments:** Check functioning of oil pressure, fuel pressure, tachometer, MP, and any other instruments which are in operation prior to flight.

- **Gas:** Check quantities in both tanks and set selector on the fullest tank.
- **Altimeter:** Set for field elevation
- **Radio:** Turn on and set primary and secondary frequencies needed.
- **Engine:** Run-up RPM to check mags, carb heat, and cycle prop if applicable. Set mixture full rich for takeoff.
- **Trim:** Set to take-off position. (for first flight, set trim at about 1/3 nose up travel.)
- **Traffic:** If non-controlled airport, check the traffic pattern for arriving and departing aircraft.
- **Extra Equipment:** (for initial flight, this might include a parachute and crash helmet. Check that they are fitted for function and are as comfortably and non-restricting as is practical. (1st flight equipment might also include a rabbits foot, 4-leaf clover, or St. Christopher medal. Avoid horse shoes, particularly from large horses, or race track losers)
- **Seat Belts & Shoulder Harnesses:** Check that they are fastened and tight. Also, check them for smooth operation and adjustment. Are the attachment ends secured and safetied?

Use any checklist you are comfortable with, as long as it includes all necessary pre-take off check items. The use of a "key" word as above is just a gimmick to help make the checklist easy to recall.

Canopy: Be sure that the latches work and are easily reached. In the event of a nose-over accident, the canopy will probably shatter and permit the occupants to exit. In the event of an in flight bail-out, an RV canopy may be jettisoned or opened. We hope. We know of nobody who has bailed out of an RV.

Electrical: Do all the radios work on all the frequencies? Do all the avionics and electric instruments perform their intended functions? Battery held down and vented? All lights functional? Ignition switch kills engine? (good ground connections?) Is it mounted securely and is the wiring behind adequately protected and separated behind the panel?

Fasteners: Cowling, inspection plates, and hatches: All fasteners in place?

PREPARATION AND INSPECTION OF THE ENGINE

Engine Operation: With the cowling removed, look the engine compartment over. Look for possible chafing of wiring, hoses, fuel, and oil lines. Secure all wiring and lines that need to be kept away from exhaust pipes. Disconnect the fuel line at the carburetor and perform a volume test on the electric boost pump. Pump fuel into a measured container and keep track of the time. The boost pump should supply enough fuel to keep the engine running at full power if the engine driven pump fails. Reinstall and double check the fuel line when you're done.

Operate the engine briefly through full power (not more than 30 seconds or as permitted by the engine manufacturer) to assure yourself that the acceleration and power is there.

Make a magneto check for both mags. Momentarily switch the ignition switch off (at idle rpm) to be sure the magneto ground connections are good and the engine will stop.

If necessary, adjust the idle rpm to that recommended for your engine. You don't want it to quit on throttling it back for landing. On the other hand, if the idle is too high, you may not be able to reduce the rpm enough to land.

When shutting the engine down with the mixture control, you should get a slight rise in rpm as the mixture control is moved to idle cut-off. Otherwise, the mixture should be readjusted.

If the engine exhibits fluctuating fuel pressure, excessively high oil temperatures, or cylinder head temperatures during ground operations, do not attempt to fly without correcting the problem. They will only become worse with the high power settings, and the relatively low speeds encountered during take-off and climb.

Finally, with the cowling and propeller spinner reinstalled, make a full power check to be sure the engine will accelerate and run smoothly at full power. Keep the airplane pointed into the wind to take advantage of the cooling air. Of course, the airplane should be chocked. It wouldn't hurt to tie it down during ground engine operations.

NOTE: Builders with a new or newly overhauled engine face a dilemma. A newly overhauled engine with chromed cylinders, or a new engine, must be broken in properly. The engine needs to be operated for several hours at high power or the piston rings will never seat. Unfortunately, this means that the engine temperatures during initial ground operation will be critical, and often the engine operations must be severely limited.

This usually precludes prolonged taxi testing and high-speed runway tests. Such a limitation, unfortunately, coupled with an untested airplane, creates a problem. It's ironic but this is a situation that gives all the initial advantages to the builder who has had to install a used engine in his airplane without overhauling it. He may not have a fresh overhaul, but neither does he have to worry about break-in problems. In addition, he can, ordinarily, perform all the taxi tests he feels he needs, concentrating on testing the airplane rather than the engine.

An untested engine in an untested airplane doubles the potential for the unexpected happening. You must, whatever the status of your engine, operate it in strict conformance with the manufacturer's recommendations. Doing otherwise could result in serious engine damage, or at the very least, will cause it to burn a lot of oil because the rings failed to seat.

When engine break-in is a concern, perform flight testing without the wheel fairings and gear leg fairings. This will add around 15% to the airframe drag and thus cause higher engine temperatures at any given forward speed. Higher cylinder head temperatures, within limits, are necessary for seating piston rings (breaking in).

Is the carb heat connected and functioning properly? With the engine running and warm, application of carburetor heat should cause a definite drop in rpm.

INSPECTION (INTROSPECTION?) AND PREPARATION OF THE PILOT

Selecting the Test Pilot: Ideally, the amateur-builder should be competent in aircraft of the same general configuration and performance as that being tested. Often, though, the expense and time of building an airplane cuts into the money and time needed to maintain pilot competence and currency. These factors should be carefully and dispassionately considered when selecting a test pilot.

A test pilot should have at least the following qualifications:

- Be physically fit. Test flying an aircraft is a stressful and strenuous occupation.
- No alcohol or drugs in the system
- Rated, current, and competent in the same category and class aircraft .
- Current medical, flight review, and paperwork.

The test pilot should:

- Be familiar with the airport and nearby emergency fields
- Fly an airplane with similar characteristics. For example, if your airplane has a short low wing, take dual instruction in a similar type-certificated aircraft such as a Grumman Yankee. If you are testing a tail wheel airplane, instruction in a Citabria or Decathlon is recommended. A pilot is competent when he or she can demonstrate a high level of skill in all planned test maneuvers.
- Study the emergency procedures for the test aircraft and practice them in a similar airplane.
- Have at least an hour of practice in recovery from unusual attitudes within 30 days of the flight test.
- Learn everything possible about the performance and flight characteristics of the test aircraft. Read the manufacturer's or designer's instructions, articles by builders, watch videos, etc.
- Review the FAA/NTSB/EAA accident reports for the test aircraft.
- Should not undertake a test flight unless he is mentally and physically in tune. While no one should pilot any airplane when suffering from mental or physical stress, this is particularly true for test flying. Even a slight anxiety which might be overlooked for routine flying, should be reason to postpone test flying
- Become very familiar and comfortable with his working environment; the aircraft's cockpit. The pilot should spend as much time sitting in the cockpit as is necessary to become comfortable. Cushions should be selected which can be used along with a parachute to provide maximum comfort under the circumstances. All controls should be operated repeatedly to become familiar with their positions and functions. This includes engine controls as well as primary flight controls.

Beginning in 1995, RV Transition Flight Training was made available through an affiliate of Van’s Aircraft Inc. Using RV-7 and RV-6A aircraft on loan from Van’s, flight instructor Mike Seager has been providing transition flight training from his base at the Vernonia, Oregon airport. In addition, Mr. Seager has also provided this service at other locations in conjunction with trips to major fly-ins such as Sun’n Fun and Oshkosh. Customer satisfaction with this training has been unanimous. The results: more confident, competent pilots flying better test programs, lower insurance premiums, and very likely, fewer bent airplanes. Check our web site for other transition training instructors.

After the pilot feels that he is sufficiently familiar with the cockpit and controls, he should enlist someone's aid to help him conduct “blindfold” cockpit testing. Just as the name implies, this is done by covering the eyes of the pilot and having him carry out commands issued by an assistant. He should be able to select and operate all controls by position only; without visual reference. This testing should include emergency procedures such as loss of power and canopy ejection. Instinctively knowing the locations of everything in the cockpit will not only prepare the pilot for emergencies, but will prepare him to do routine flying with more accuracy, thoroughness, and confidence. (Rumors have it that spending time sitting the cockpit of unfinished airplanes is a pastime enjoyed by many builders. We understand that in some instances, this pastime is enriched by the would-be test pilot making engine sounds, and sometimes even machine gun sounds)

PRE FLIGHT PLANNING

An RV in proper trim is not difficult to fly or land. However, if the RV is a taildragger, the pilot should be proficient in tailwheel aircraft before attempting to fly one. Similarly, he should, if possible, have some exposure to aircraft with light control forces and quick response rates. But perhaps as important, he should plan his flight test program to systematically experience and evaluate all normal and emergency flight conditions. If the builder chooses to have someone else do the test flying, he should seek a pilot who not only has the necessary flying skills, but also the discipline to conduct the flight test program in a professional manner. This is opposed to the reports often heard about pilots of homebuilts who, on the first flight, take the plane up and “wring it out”.

Some old Hollywood movies present the typical flight test scenario as one where the handsome, devil-may-care test pilot climbs the plane to its maximum altitude, puts it in a full power vertical dive, and after a seemingly endless descent punctuated with flashbacks and trauma, recovers just feet above the treetops. He is a hero, he wins the undying love of the leading lady, and his company gets the fat military/airline contract.

Sometimes it seems that this test flying image has become so ingrained in our aviation mentality that it is thought to be valid. Really, it bears little resemblance to test flying practiced today, whether in fighters or homebuilts.

In addition to the skill and proficiency considerations, a test pilot should be psychologically prepared. He should not be rushing to the extent that he is too tense and uptight to react properly. All pressure producing factors should be eliminated if possible. These include such things as pre-established test dates or times and large audiences. The important factor is that the pilot attempt the first flight only when he is totally ready. Typically, the builder has many friends who want to see the first flight, and in many cases there is a tendency to want newspaper and TV reporters on hand. While there is nothing inherently wrong with this, it does distract the pilot from making his flight preparations and cause him to attempt the first flight when wind and weather conditions are not ideal. We witnessed one test flight by a very experienced professional pilot in an airplane (not an RV) which was unknowingly badly out of rig. Nearly full aileron was needed to keep the plane level, and after one circuit of the field, the pilot barely had enough strength left in his arm to keep it level for landing. When asked why he didn't immediately land after lift-off (5000 ft. runway) he said “I didn't want to disappoint the crowd”. This is obviously dumb. One way to prevent such dumb decisions is to eliminate the crowd. It would be better for the pilot to do the test flying in relative privacy and then invite friends and press out to see the “official” first flight.

WEATHER

The first flight of your RV should be attempted only under the best possible conditions. The best time to fly is early morning or late afternoon. The wind should be calm or light and right down the runway. Conditions are seldom ideal, but don't be so eager to fly that you accept gusty or crosswind conditions that will add to the workload of a first flight.

EMERGENCY PLANS AND PROCEDURES

On the way to the airport and after you get there, review your emergency plans, procedures and ground support needs.

Know what your ground support can and will do. Hopefully you did not invite a crowd. No first flight needs such distracting or tension inducing factors. This is not an air show. However, the first flight of a homebuilt, for most of us, is a once-in-a-lifetime event that should be appropriately covered. Try and get someone with a telephoto lens or video recorder to do the honors.
Emergencies do happen -- usually when they are least expected.
KNOW what you are going to do IF:

- The engine quits on takeoff.
- There's a fire on board and the cockpit fills with smoke.
- The airplane is terribly out of balance and very hard to control.
- You lose communications with your tower, support crew, or chase plane.
- The propeller throws a blade, or the spinner breaks.
- The throttle jams, full open, full closed or in between.
- One of the controls jams or a cable breaks.
- The engine temperatures rise rapidly past redline.
- Oil begins appearing on the windshield and the oil pressure drops.
- The canopy comes open unexpectedly.

Obviously these are not the only things that can happen without warning on that first test flight; however, they are probably the most life threatening.

Prepare yourself mentally and review the options and logical corrective actions you would take for any of these eventualities.

Keep this essential in mind. You must, regardless of what sort of airborne emergency arises, continue to fly and control that airplane.! DON'T LET IT STALL!! KEEP IT UNDER CONTROL!!! Fly it all the way to the ground if you have to, but the key words for survival are DON'T LET IT STALL!!

A stall too near the ground to permit recovery will usually result in greater damage and injury than would occur if the aircraft hit the ground at its best glide speed and angle. It is a normal tendency for the pilot to slow the aircraft to its minimum speed to try and reduce damage during a forced landing. But, an aircraft, which has stalled, is temporarily out of control, usually in a nose-down attitude. While it may have been at minimum speed just before the stall, it will probably have gained considerable speed by the time of impact. Even if it didn't, the impact angle will probably be steeper.

Injuries in aircraft crashes are the result of rapid deceleration. The shorter the stopping distance, the greater the deceleration rate. If the aircraft contacts the ground at a steep angle, the stopping distance will obviously be short, and the rate of deceleration high.

If the aircraft hits the ground at a shallow angle, its stopping distance will be greater. Even if the contact speed was higher, the deceleration rate will be less and the landing will be more survivable. Many factors, such as terrain and obstructions, will also affect the survivability of the crash, but the bottom line is that a controlled crash is better than an uncontrolled one.

If an accidental stall should occur during the early stages of an emergency (just after an engine failure or while trying to turn back, for instance) an innate, subconscious knowledge of stall recovery will be invaluable. As contact with unfriendly terrain becomes imminent, these words should echo through the pilot's mind: DON'T STALL!! KEEP THE NOSE DOWN!! DON'T STALL!!

SELECTING THE RIGHT AIRPORT

One of the first important decisions you must make is selecting an airport for flight tests.

Runways and surroundings: The airport you select should have at least one runway aligned with the prevailing wind. The runway should have the proper markings and a nearby, easily visible wind indicator. Avoid airports in highly developed areas or with heavy traffic. To determine the needed runway length you can use the following rule of thumb:

The runway should be at least 3000' long and 100' wide. If you are testing a high-performance aircraft or intend to operate at high density altitudes, the runway should be 5000' or more and at least 150' wide, for a greater margin of safety.

Scout emergency landing fields within gliding distance from any point in the airport pattern. Since 1983, engine and mechanical failures have accounted for 38% of amateur-built aircraft accidents. Since there is a possibility of this type of emergency occurring, appropriate preparations should be a mandatory part of your Flight Test Plan.

Communications: Even if the test aircraft is not equipped with a radio, it is still a good idea to conduct flight tests from a field with an active Unicom or a tower. Those using an uncontrolled field should set up their own communications base. Small, hand held radios should be borrowed or rented. The pilot should have a headset and a push to talk switch mounted on the stick. These help reduce the pilot workload. The added insurance of radio communication more than makes up for the rental fees.

Equipment: Your airport should have fully functional telephones, rescue, and firefighting equipment.

Other: Additional considerations when selecting an airport include available ramp and hangar space. You will need a place to run-up your engine and test aircraft systems on the ground, without fighting inclement weather, or distracting bystanders.

Make an appointment to talk with the airport manager, or owner, about your Flight Test Plan and emergency preparations. He or she may be able to assist you with communications, space or equipment.

EMERGENCY PLANS AND EQUIPMENT

Every test of an amateur-built aircraft should be supported by a ground crew; usually between one and four people. Their function is twofold: first, to help the pilot with the flight test and second, to assist in case of an actual emergency.

Every builder should develop two sets of emergency plans, one for in-flight emergencies, the other for trouble on the ground. The ground emergency plan should include a briefing for the ground support crew and airport fire/rescue crew on:

- the cabin door or canopy latching mechanism
- the pilot's harness and its release mechanism

- the location and operation of the fuel shut-off valve
- location and operation of the master and magneto switches
- battery location
- engine cowling removal procedures.

Everyone on the ground team should know the locations and phone numbers of the nearest hospitals, fire and rescue squads. If the test pilot has a rare blood type or is allergic to some medications, these should be noted and left with the ground crew. A "medic-alert" bracelet is also a good idea.

There should be several fire extinguishers available to the ground crew and a halon fire bottle in the cockpit. The pilot should have a tool capable of breaking or cutting through the canopy from the inside.

If the airport does not have a fire rescue unit, a four-wheel drive vehicle equipped with fire extinguishers, first-aid kit, tools to cut through metal, and a crew trained in first aid is a must. Sometimes, for a small donation to cover expenses, volunteer fire rescue squads will stand-by and offer the extra insurance of a trained emergency team.

The possibility of fire should be considered during all phases of flight test. Ideally, the pilot should wear coveralls and gloves of Nomex, but if this is not available, all clothing should be cotton or wool. Synthetics like nylon or polyester melt and stick to the skin when exposed to heat, making a bad situation much worse. A crash helmet and face-shield or goggles provide protection from flame, smoke or hot fluids. Protection from impact demands a helmet, or at the very least, a hard-hat, and a correctly installed and adjusted shoulder harness.

Professional test pilots always wear parachutes. "Homebuilder" test pilots often don't, probably because of the scarcity of parachutes in the private flying community, and the limited cockpit space for this extra piece of flight test equipment. Also, many homebuilders apparently view testing more in terms of a "check out" because their kit built RV is not the same as a radically new experimental design. However, because it *is* an amateur built airplane and because the airframe and systems *are* new and untested, we encourage builders to secure the use of a parachute to wear during testing. At the very least, a parachute should be worn while conducting limit testing, such as testing maximum speeds, G loads, and spin testing. The probability of needing the parachute is very low. However, if you happen to draw the short straw, it sure would be nice to have that "personal vertical descent retardation device" available.

Probably the simplest and most effective safety device is a good helmet. Crop dusters, helicopter pilots and test pilots have all made these standard equipment, and you can be sure they have good reasons.

PERFORM A PREFLIGHT CHECK

No matter what you know or think you know about the condition of your airplane, and no matter how recently you checked everything, perform a complete preflight check. Not only is it the law, it's a good idea. Use a prepared preflight check list. Do NOT overlook:

- The ignition switch is OFF, the throttle is retarded, and the wheels are chocked.
- Pull the prop through five blades. Check for compression on all cylinders, the little click that tells you the impulse coupler is working, visual inspection of the prop and spinner.
- Visually check the fuel and fuel caps. Use a dipstick. Drain a goodly amount of fuel from the sumps and check for water.
- Clean and polish the windshield.

OTHER IMPORTANT PREPARATIONS

Try and plan for all possible contingencies.

Transport: Assure yourself that your standby crew knows where the nearest phone is located and that they have the EMS and fire emergency numbers.

A car should be available and your dependable standby crew should have tools, a fire extinguisher and a first aid kit onboard--and possibly a two way hand-held radio.

Chase Plane. A chase plane can be used to monitor the first flight if a qualified pilot and observer are available. A qualified pilot is one capable of flying in formation close enough to permit viewing of your airplane to verify control surface positions, oil streaming out of the cowl, etc. The primary purpose of a chase plane is safety. A secondary purpose is as a camera platform to record this historic first flight. However, never confuse these two goals and become too intent on the photography function. The test flight should not be unnecessarily extended in time or geography just for the sake of getting more photos or video time. Also, proximity of formation flight and/or maneuvers for photo purposes should not be allowed to compromise safety. Keep your priorities in order.

Pilot & Crew Briefings: Before your first flight, brief your crew and/or chase plane pilot of your intentions. Discuss your intended flight sequence and emergency procedures. Make sure that your chase plane pilot realizes that he is always to keep out of your way, or be prepared to get out of your way at any time an emergency may arise. Discuss radio frequencies to be used or hand signals to be used.

How will you know when the airplane and test pilot are both ready for the test flight? When you can no longer find any reason not to!!!!

TAXI TESTS

Try a number of taxi tests, no faster than a slow walk, to familiarize yourself with the steering and braking effectiveness, and to become proficient in handling the aircraft on the ground. Learn how much runway or taxiway width is needed to turn the airplane around. Pilots of tail wheel aircraft can make good use of the taxi experience to establish an over-the-nose attitude reference to help in making the first three-point landings.

If you decide to perform high speed taxi tests remember the real purpose for high speed taxi testing is to learn how the airplane feels or behaves just before reaching lift off speed, and just after touchdown.

For safety's sake, select an abort marker about halfway down the runway. You should be able to cut your power when you reach that point and still have sufficient runway left for a safe stop without burning up the tires and brakes.

High speed runs down the runway must be limited to approximately ten mph below the anticipated lift off speed, or about 40 mph. Therein lies a problem. An RV can take off at throttle settings no higher than those needed for engine run up and mag check. Thus, an inexperienced pilot who accelerates to 30-40 mph and then reduces power in an attempt to maintain that speed will probably retain too much power and continue to accelerate up past minimum flying speed. As a result, he may find himself up the proverbial creek without the paddle, or more accurately, off the ground without a plan.

Never attempt high-speed taxi tests until *both the airplane and the pilot are prepared for flight.* Accidental lift-offs during high speed taxi testing are not uncommon, and often lead to unnecessary accidents. It has happened to a number of RV builders.

Make a couple of runs with and without partial flaps. Half flaps is the recommended take-off setting. For a tail wheel aircraft this will cause the tail to seem lighter (easier to lift), and will shorten the take-off roll slightly for either tail wheel or tri gear models. .

Pay attention to the amount of rudder input necessary to counteract engine torque and to keep the airplane straight on the runway. Watch out for rapid applications of throttle at low speeds.

Glance at your airspeed indicator during the high speed runs to make sure it is working.

Monitor fuel and oil pressures, oil temperature, and cylinder head temperature. If any of these are suspect, return to the ramp immediately.

Keep the tailwheel on the ground with stick back pressure at low runway speeds until rudder effectiveness is obtained, especially in crosswind conditions. Be very careful when the throttle is reduced after a high-speed taxi run and the tail starts to settle. Inadvertent back pressure on the stick (too soon and too quick) might cause an unexpected lift off and difficult runway control problems.

“Controlled lift-offs," particularly on a runway less than 5000 feet long, are dangerous and should not be attempted by inexperienced test pilots.

THAT FIRST FLIGHT

With all the above completed, along with the other preflight items for your airplane, you are ready to go. Give your last minute instructions to your ground crew. Complete your pre-start checklist and start the engine.

Check your oil pressure and the rest of the instruments. Switch tanks and run the engine off each tank. Set the fuel selector to the takeoff tank. Taxi to the runway and complete your pre-takeoff checklist.

Clear the area, including the runway, announce your intentions and begin the takeoff roll by advancing the throttle smoothly to FULL power. Check for rpm and oil pressure. If you are not airborne by midfield, abort the takeoff. Allow the airplane to fly itself off with light back pressure on the stick--don't pull it off. Guard against an excessively nose high attitude.

Should you feel a vibration immediately after takeoff, try the brakes. Your tires may be out of balance. Immediately feel out the controls. Gently! Don't over control.

Check your airspeed indicator at liftoff. This will assure you the instrument is working and give you a rough idea of landing speed.

Climb out at a shallow angle, easing the flaps up if you used them for takeoff. Start a gentle turn as you pass through

500' AGL so you won't get too far from the field.

Don't even think of changing the throttle unless engine temperature or rpm limits are being exceeded. Many engine takeoff failures seem to be related to the initial power reduction.

Turn off the fuel boost pump.

Check the engine pressures and temperatures. Staying over the airport, climb to 3000' AGL.

At altitude, reduce power and trim for cruise flight. Keep monitoring the engine gauges and be alert for strange vibrations or noises.

Everything is OK? Good. Relax.

Clear the area and make a few approaches to stalls, both power on and power off. Complete stalls are not necessary. Merely slow the airplane to the point where the controls get mushy or you detect a light pre-stall buffet. Note your indicated airspeed. Also note the nose-high attitude at stall which will be approximately the same as the landing attitude. Repeat the approach-to-stall exercise with half flap and then full flap conditions. Note the pressure needed to bring the plane down to stall speed, and the difference in pressure with and without flaps. Avoid the temptation to try anything more, other than practicing some shallow and medium bank turns. Gliding turns can also be practiced, concentrating on maintaining a steady speed of about 90 mph IAS. There will be plenty of flights after this one to explore other flight regimes and maneuvers. The first flight should be short -- 30 to 40 minutes. Relax and have the chase plane come in closer to visually check over your airplane, and make some videos. While you're flying side-by-side, compare airspeeds and power settings, especially at approach speeds.

LANDING

Complete your pre-landing checklist. Announce your intentions and enter the pattern. Make your approach speed 1.5 times the approach to stall speed you noted earlier, usually around 80-90 mph for a typical RV. On landing approach base leg, one notch (or about 20°) flap setting should be applied. One notch, 1/2 flap is suggested for the initial landing. The 80-90 mph approach is a little faster than ideal approach speed, but will be best for the first landing attempt because it will permit more time to execute the landing flare. A tail low, "three point" landing is suggested for the first attempt. Remember the nose high attitude experienced in the power off stall approaches. If the wheels touch before you have fully flared the plane, just release a bit of back pressure to prevent ballooning into the air again, and call it a semi-stall landing. If you should accidentally hit hard enough to cause a sharp bounce back into the air, apply power and make a go-around for another landing attempt. Unless the runway is very long, it is probably better to start over rather than to try to salvage a bad landing out of an abnormal condition (bouncing back into the air at an unusual attitude or speed.)

On tri-gear planes, land on the mains and hold the nose wheel off as long as possible. The nose wheel is taxiing gear, not landing gear. Keep the stick full aft while you taxi.

Try to touchdown a safe distance past the threshold. Concentrate on keeping the airplane straight and let it roll out. Stay off the brakes if you can.

Taxi carefully back to the ramp and to the congratulations you have earned. It's OK to wave and grin at your friends now.

POST FIRST FLIGHT

The initial test flight proved your airplane will fly and that it is controllable. Now you have to prove to yourself that it can perform safely under a variety of service conditions. This means you should now begin to gradually and carefully expand its flight envelope. Approach the second flight with the same concentration and preparation of the first. After all, there's still much you don't know about this airplane.

For example, your initial flight was probably made with less than full fuel and with a minimum payload. But how will the airplane behave with full fuel, and at gross weight? Will the CG stay within safe design limits?

Although you may have been pleased with the controllability and flight characteristics exhibited on that first flight, be realistic and accept that you may yet have to face up to some quirks that may not show up until all limits of the flight regime are explored.

At this early stage, it's normal to experience a degree of a concern regarding the airplane's controllability in the high speed ranges, and most of all regarding its freedom from flutter. These particular evaluations are considered critical and are potentially the most dangerous characteristics to explore. The only way to get all the answers is by working the airplane through a variety of flight conditions while gradually working up to the maximum performance limits.

EXPANDING THE ENVELOPE

Before you fly again, check the conditions in the engine compartment. You can't be too careful at this stage. Remove the cowling and look for fuel and oil leaks, loose clamps, wiring problems, and the security of all installed components. It might be advisable to remove all the inspection covers and check inside. Repeat this inspection every ten hours or so for the test period.

Start your evaluations by systematically performing all ordinary maneuvers. They should include the following:

- climb performance tests
- service and absolute ceiling tests
- slow flight
- stalls
- stability tests
- airspeed calibration
- fuel consumption
- prop evaluation
- CG loadings
- performance checks

Other, more potentially dangerous tests, may be deferred. These include spins, flutter testing, and aerobatics. Each new maneuver and test will reveal more and more about the airplane. In addition they will sharpen your skills in handling your new craft.

Repeat tests, if necessary, until you are satisfied with the airplane's responsiveness and your abilities. Don't slight any of the easy, simple-to-do tests-- you're not going anywhere for the next 25 to 40 hours anyway.

It's a sobering thought, but you must realize that every test involves some element of risk. Think through and rehearse your options ahead of time. Prepare as best you can for the unexpected.

PERTINENT THOUGHTS

Plan to devote the first portion of each flight to one or two test elements. Don't waste time simply boring holes in the sky. Know exactly what you want to accomplish during the flight before you take off. Think out how you will do it and approach every test carefully and cautiously. Complete only the test items you have planned - no more. Then you can spend a bit of time sight-seeing and enjoying.

Record all your observed results -- instrument readings and flight data. Use a kneeboard or a small pocket recorder. Don't trust to memory.

Tests flown in windy or turbulent weather are often so inaccurate as to be useless for recording performance data. Pick your weather carefully.

After each flight, debrief yourself. Review what you did: wrong and right. Give yourself time to absorb what you have learned.

Whenever some small problem occurs; some unexplained vibration, a slight binding of the controls or the like, correct it before the next flight. NEVER let things go.

CARRYING PASSENGERS DURING PHASE I TESTING:

FAR’s dictate that during Phase I testing of Amateur built aircraft, the aircrew shall be limited to essential crew only. Van’s Aircraft, Inc. interprets this in RV’s as solo.

TYPICAL TESTS

Best Rate Of Climb: Use full throttle and check the rate of climb for several different airspeeds. Start at a fairly low altitude, stabilize your airspeed in climb and begin your timing as you pass the next thousand foot level. Note the time as you pass through each thousand feet of altitude. Make climbs of 4 to 5 thousand feet altitude gain. Normal anticipated indicated climb airspeeds will vary from 100 to 140 mph. Repeat the climb tests for each airspeed so that differing readings can be averaged.

Best Angle Of Climb: After climb tests have been made at normal anticipated speeds, perform timed climbs at indicated speeds of 90 IAS, decreasing in 10 mph increments, down to 70 mph. At the lower speeds, watch cylinder head and oil temperatures carefully to avoid overheating. Limit low airspeed climbs to 2 minutes or less for cooling reasons.

Plot Climb Charts: Following the procedure outlined here, plot on graph paper a climb curve for various airspeeds. After the points have been located for climb rates at different speeds, draw in a smooth curve which connects all points. Because of testing inaccuracies, the climb curve can be drawn to a smooth shape which approximately contacts the points. The speed for maximum climb rate is that at the top of the curve. As the speed increases past that point, the climb rate will decrease until it is zero at the airplane's top level flight speed.

Draw a straight line from the 0-0 beginning point of the chart up to a point where it is tangent to the curve. This point will be the BEST ANGLE OF CLIMB SPEED.

Plot another curve of climb rate vs. altitude for the best climb rates for each altitude. The best rate of climb will of course be at the lowest altitude, and will decrease with increasing altitude. A line connecting these points will be a straight line, and an upward projection of this line will provide the theoretical absolute ceiling of the airplane. The service ceiling would be the altitude at which a 100 fpm climb rate is indicated. On the other end of the line, where it intersects the “0” altitude line, will be the SEA LEVEL climb rate. Using these graphs, reasonably accurate ceilings and sea level climb rates can be found without ever flying at those exact conditions.

Slow Flight: The idea is to become familiar with the trim and attitude changes that take place while you are trying to maintain your altitude at minimum flight speed. Careful, you could stall unexpectedly. Do these maneuvers at a safe altitude. Try a few level turns with and without flaps. But, do a lot of slow flight practice. Practice until you can consistently maintain speeds within 5 mph above stall speed while transitioning from wings level through 15-20 degree banks to the right and left. The idea is to become so familiar with slow flight that it can be done almost subconsciously; being able to devote thought to traffic and other considerations at the same time. You want to be very familiar with the slow flight mode so that you are able to make landing approaches safely even with the distractions which are bound to occur, and to be able to detect the approach of stall speed even while dividing your attention to other factors such as traffic and ground obstructions.

However, watch your engine temperatures while practicing slow flight. The reduced cooling airflow, coupled with the relatively high power required for slow flight, will cause the engine to heat more than at cruise conditions. Slow flight practice sessions will probably have to be limited in duration for this reasons.

Years of experience gained from reviewing accidents and flight control problems have shown that a better mastery of slow flight could have prevented many accidents and minimized flight difficulty problems. ABE accident statistics show that 18% of accidents occur on takeoff and 33% on landing. Both of these flight regimes involve slow speed flight and the need for control under these conditions.

Takeoff: There are a few critical seconds following takeoff where flight must be controlled within a few mph of stall speed and where wind turbulence can significantly affect attitude, controllability, and airspeed. Even further into the takeoff/departure sequence, climb speeds can deteriorate to critically low margins because of turbulence, wind shear, obstacle clearance requirements, and other distractions.

Landing: The historical evidence of landing approach stall/spin accidents should be sufficient evidence of the need for a high level of pilot familiarity with low speed controllability. Slow flight skills are also of great importance to the final phase of the landing; pre-touch down. Particularly for tail wheel airplanes making full flare, 3 point landings, the last few seconds preceding touch down are crucial. Look at it this way. The pilot must keep the airplane under control within a few feet of the runway, within a few mph of stall speed, and in a straight line relative to the surface. Are these the circumstances under which slow flight should be learned? Of course not! Learn at altitude when time and distance(altitude) are in your favor. Then as you approach the critical landing sequence, many of the needed skills will have already been acquired.

Gliding Tests: In the event of an engine failure, it would be nice to know what airspeed will give the minimum gliding angle. These tests, logically, are most effectively performed following your climb tests because you could then use the altitude gained.

Start with plenty of altitude and complete your last practice turn at least 1000' AGL. Clear your engine briefly after each 90 degree turn. If you don't have a VSI, time your descent through different thousand foot levels.

To learn how your airplane behaves in gliding turns practice a few and note how the rates of descent change with airspeed and bank angle. It is important to keep your gliding turns coordinated. Try doing them at different airspeeds and record your observations.

Practicing these gliding turns is essential because you will be duplicating them each time you turn final for landing. Be careful -- an excess of uncoordinated rudder input (slip or skid) and excessive back pressure on the stick can cause the airplane to snap over the top, or snap under to an inverted attitude. At traffic pattern altitude, this can be fatal.

Determine and record how much altitude is ordinarily lost in making a 90 degree gliding turn, a 180 degree and a 360 degree turn. Make similar checks with partial and full flaps.

Plot Glide Speeds: On the same graph as climb performance, plot points for gliding rates of descent (sink) at various speeds tested. In addition to the rates of sink listed for the various speeds, a tangent line can be drawn to find the speed at which the best glide angle can be attained. By converting MPH to FPM forward speed, and then dividing by the sink rate in FPM, the glide ratio can be found.

While these sink rates and speeds are valuable guidelines, they are not totally representative of those which might be experienced during an actual engine failure emergency. At idle power, a fixed pitch RV will show a better glide ratio and angle than it will at zero power and the prop windmilling. The glide ratio with the prop windmilling (no combustion) will be better with the throttle open than if it were closed. The bottom line is that the pilot should be able to visually access the glide performance on the spot and plan his power off approach accordingly.

Engine Cooling Checks: Monitor and record engine temperatures on every flight. However, you should also study and record the effects produced by aggressive mixture control manipulation, changes in airspeeds, and changes in power setting. Prolonged climbs and glides will probably produce dramatic changes in engine temperatures and you should know to what degree. Remember, hot summer free air temperatures can intensify high engine temperature indications - often to a critical degree.

STABILITY INVESTIGATIONS

One of the more subjective areas of flight testing is that of aircraft stability. It is necessary to check for stability in all three axes, LONGITUDINAL (pitch), LATERAL (roll), and DIRECTIONAL (yaw.) Stability testing cannot be accomplished until the airplane has been checked for trim and any external tabs needed have been installed and adjusted to permit control free (hands off) flight. Before describing how to perform stability checks, we'll first define what the various forms of stability are.

- *Longitudinal (Pitch) Stability*: The tendency to remain at a constant trim speed, and to return to a that trim speed after being displaced by a pitch control input.
- *Lateral (Roll) Stability:* The tendency of the bank angle to remain constant, or to return to wings level.
- *Directional (Yaw) Stability:* The tendency of an airplane to maintain a directional heading when wings are level (no roll), and to return to a steady heading after release of a yaw input control (rudder).

Before describing the testing procedure, lets review some theory:

C.G. Considerations: While performing stability checks, it is important to that the pilot recognize the effects of the position of the C.G.

Pilots have all been exposed to the term "aft center of gravity" and are aware that this is a condition which has limits and is normally referred to in a precautionary tone. But, how well do you understand all of the ramifications of aft C.G. conditions? Perhaps you know that this is a condition to be avoided when doing aerobatics, but do you know how to recognize the symptoms of aft C.G. in normal flight conditions, or the problems which may be encountered under "normal" conditions as a result of an aft C.G. condition?

Fig. 15-1 shows the basic forces acting on an airplane. This airplane is designed to have positive stability with the C.G. located as shown. It is in equilibrium at a design cruise speed. The nose down tendency caused by the C.G. being forward of the center of lift (C.L) is balanced by the stabilizer down load resulting from the negative incidence angle (relative to the wing angle) of the stabilizer. So, a constant static load is balanced by an aerodynamic force which will vary with airspeed. If the aircraft's nose is lowered, an increase in speed will result, and that will cause a greater down-load on the stabilizer, which will in turn raise the nose again to bring the speed back to where it started. The converse will happen if the nose is raised. However, the aircraft will normally overshoot its original trimmed attitude and speed. Thus, there are usually several cycles of pitch hunting required to return to stable flight. Each cycle is of decreasing amplitude (altitude variation). These pitch cycles are called "phugoids".

Fig. 15-2 shows the aircraft loaded to a more forward C.G. condition, for which an elevator trim force is needed to maintain equilibrium. Generally, a nose heavy airplane is more stable because of the greater difference between the static weight position and the dynamic force of the trimmed elevator.

Fig. 15-3 shows the aircraft loaded so the C.G. and the Center of Lift are at the same point. Thus, no stabilizing trim load would be required of the tail. But, if there is no trim load, there no restoring load, and thus no positive stability. In this condition the aircraft would have neutral stability. It would continue to fly at whatever attitude it is placed or displaced to.

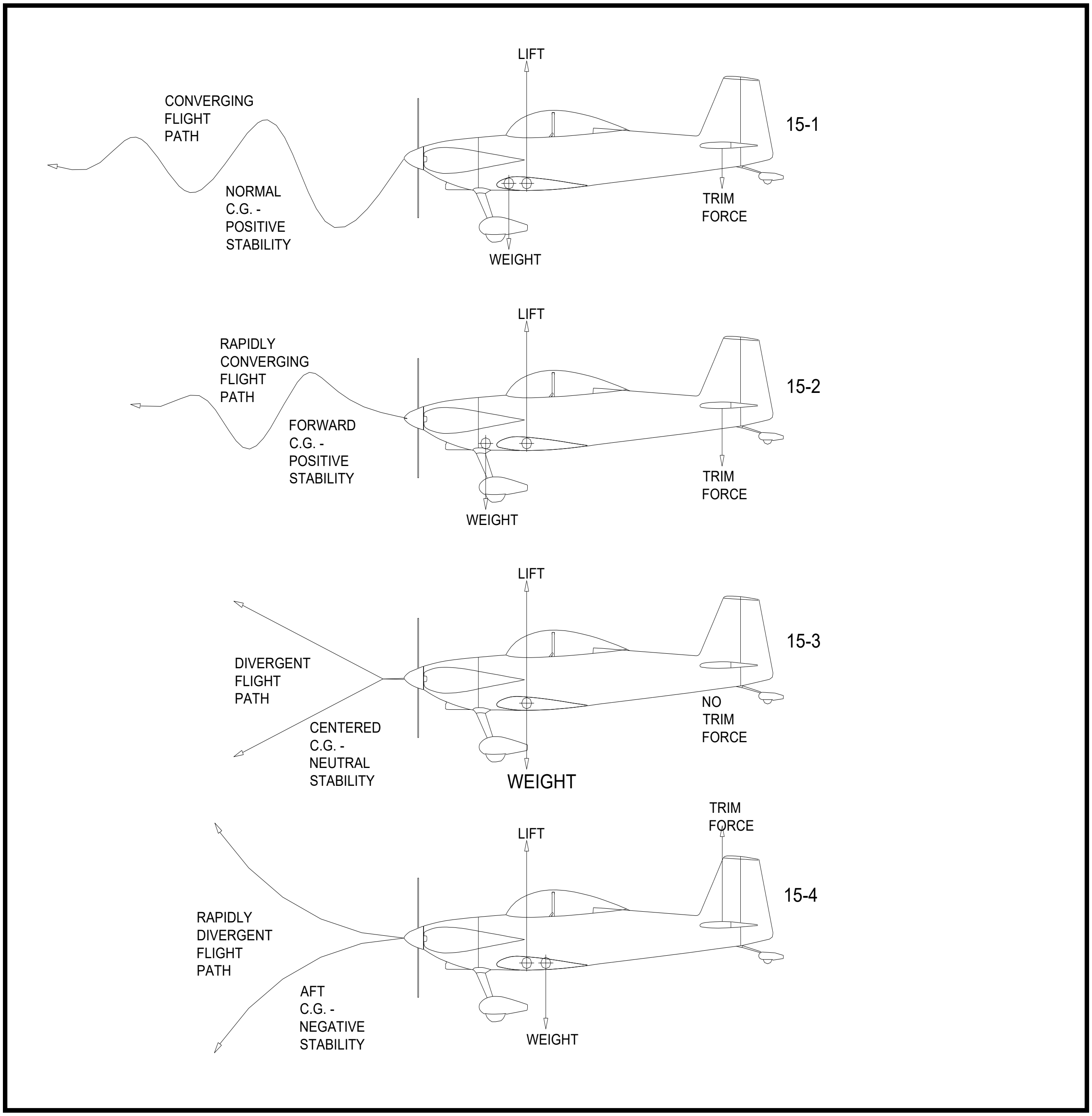
Fig. 15-4 shows the aircraft loaded to an extreme where the C.G. is aft of the Center of Lift, and where the horizontal tail surfaces must produce a lift force to maintain level flight. In this condition, when the nose is lowered, speed will increase and the stabilizer force will increase. But, since it is a lifting force or upload on the tail, it will continue to lower the nose and produce more lift and more speed. etc. If the nose were raised and the speed decreased to below trim speed, the reverse would occur; speed would continue to drop until a stall occurred, recovery from which would be difficult and spin entry would be probable. This is an unstable condition because the forces acting on the aircraft are destabilizing with a change in speed. In this condition the aircraft is PITCH DIVERGENT and is extremely difficult to fly and dangerous.

In summation, as the C.G. moves aft the aircraft will go from having positive stability, to neutral stability, and then to negative or divergent stability. The drawings show the aircraft with neutral stability retaining the attitude to which it has been pitched. The negative stability aircraft is shown with a flight path diverging from the intended flight path.

Not all airplanes will respond to C.G. positions exactly as shown because most airfoils exhibit a shift in their center of pressure as speed changes. This simplified explanation is sufficient to understand the basics of pitch stability.

FLIGHT TEST PROCEDURE:

Longitudinal Checks: Trim for level flight at cruise power. Raise the nose to lower the speed to 10 mph below trim speed. Release the stick. The airplane should nose down and the airspeed will increase to above the initial trim speed. Then the nose will again begin to rise and the speed will again fall to a value below the trim speed. This process will repeat itself for 3 to 4 cycles with decreasing speed excursions until trim speed is again established and



maintained. This is an acceptable phugoid behavior and will approximate the flight path depicted in Fig. 15-1 and 15-2. This test should first be done at a forward C.G., usually solo. Then repeated with progressively more aft loadings up through the aft limit. All RV models should exhibit a positive pitch phugoid.

However, at aft loadings, the phugoid will be very long.

It is essential that the atmosphere be very stable while conducting these tests. If not, the results will be inconclusive. Also, the aircraft must be in good roll and yaw trim so that stick free flight can be maintained over a period of minutes needed to experience a complete series of dampening phugoid cycles. Because RVs tend to have neutral roll stability, and because of limited yaw/roll coupling, (rudder input has very limited effect on roll) it is often difficult to maintains wings level for these tests. A light string or rubber band can be attached to the top of the stick and used to apply a light roll correction without disturbing the pitch trim (stick freedom).

Repeat this test at an airspeed of 1.5 Vs (clean stall), or about 90 mph IAS. At this speed a typical RV exhibits weaker pitch stability than at cruise speed.

The worst pitch stability configuration will be a full power climb at low speed such as the 1.5 Vs condition. Particularly at an aft C.G., an RV will probably exhibit neutral or negative pitch stability. RVs with higher HP and/or low pitch (CS) props will be the least stable in this condition because of the pitch-up effect of higher thrust. Also, steeper climb angles associated with high thrust will diminish stability due to the adverse pendulum effect of the C.G. vs. the Center of lift of a low wing aircraft.

From the above flight test observations, we have learned that greater pilot attention will be needed under certain conditions. Since pitch stability will be less at low speed/high power conditions, the pilot must be more vigilant about monitoring indicated airspeed. For instance, during a steep departure climb a pilot can easily become distracted from monitoring airspeed, or the effects of turbulence can alter airspeed control.

The reduced stability of the power climb profile will be further accentuated in the classic very steep climb following a buzz job. Many pilots have been lost through attempting this dumb show-off stunt through lack of attention to the fundamentals covered above.

Stability and its Adjustments: Aircraft stability is rather complex field, generally beyond the grasp of the average builder/pilot. We will attempt to explain a few of the basics to test and what to watch for. The most obvious is probably pitch stability. When loaded within C.G. limits, an RV should have positive pitch stability. This means that when it is displaced in pitch (nose up or down) from a previously trimmed speed, it will return (hands off) to this trimmed speed within three oscillations. Factors, which might counter this stability, are aft C.G. loadings, and elevator trailing edges with a greater radius than the plans show. A large radius trailing edge on the elevator would tend to give lighter stick loads, and would probably manifest itself in a “hunting” or horizontal bobbing tendency. If so, a correction can be made by decreasing the radius by the clamping block method described in the empennage section of this manual.

When flying in turbulence, the aft loaded, less pitch-stable airplane will tend to pitch up or down due to the turbulent air and that pitching will intensify in magnitude unless corrected by the pilot. RV Pitch control forces are light and any over-controlling will require an opposite pressure to correct. A pitch divergent airplane will be much more demanding to fly and much more dangerous as well. Rather than a designed balance of weight and aerodynamic forces, the pilot is required to supply stabilizing control forces.

Production airplanes have had C.G. limits established which if adhered to will prevent the airplane from exhibiting characteristics of neutral or negative stability. The same is true for our RV sportplanes. However, because the testing of our prototype airplanes is not necessarily as technologically advanced and thorough as factory testing of type certificated airplanes, and because each of the RVs has a different manufacturer (homebuilder), we are less able to assure uniform stability characteristics for all RVs. For factory airplanes as well as for RVs flown at or near the aft C.G. limits, control responses approaching those described for neutral stability can be expected.

The normal loading of an RV, particularly a tandem seat RV-4 or RV-8, results in wide shifts in C.G. position. Aerobatics, because the associated unusual attitudes, are much more likely to result in accidental stalls and spins, than is non-aerobatic flight. Aerobatics performed at an aft C. G. condition can be hazardous both because of the light pitch control forces which can lead to accidental stalls and spins, and because recovery from those stalls and spins will be more difficult because of the aft C.G. In addition, the light pitch control forces and reduced pitch stability lead to the possibility of over controlling and thus over stressing the airframe.

For non-aerobatic flight, the aft C.G. condition is still a serious concern for normal everyday flying. This is primarily because of the statistical prominence of the landing approach stall/spin accidents. Light planes of all types have been plagued with this curse ever since the early days of powered flight. The compromise, which sport aircraft designers have to make, is between airplanes with very limited control authority and good stall/spin resistance, and those with good control authority and a lesser degree of stall/spin resistance. This design compromise is evident in all light aircraft with the exception of a couple of purportedly “spin proof” airplanes. In the RVs, the design choice of strong control authority for aerobatics and STOL flying has relegated some of the responsibility for stall/spin avoidance to the pilot.

Now, just what does this mean to the pilot; what changes in control forces and control response does he experience when flying at or near the aft C.G. limit? When flying in a condition of equilibrium the pilot doesn't necessarily notice any difference between the loading conditions. But, as soon as any pitch maneuvering is initiated, or turbulence upsets the stable pitch attitude, handling qualities are noticeably changed. The stabilizing force will be slight---it will take much longer for the aircraft to return to trim speed if flown hands-off.

However, pitch control (elevator) forces will be much lighter, increasing the possibility of over controlling.

It is obvious that the effects of an aft C.G. position on pitch stability demand extra attention to airspeed control when flying near minimum speeds. Very little change in control stick position and pressure will be need to induce a stall. Since landing approaches are made at near minimum speeds, coupled with the distractions of air and ground traffic, tower conversations, crosswinds, turbulence, and low altitude turns, they constitute an ideal situation for an accidental stall. An aft C.G. just makes an accidental stall easier to encounter, more prone to degenerate into a spin, and more difficult to recover from if it does occur.

To avoid falling prey to a approach stall/spin accident, pilots should do several things:

- He should practice slow flight with the aircraft loaded at or near aft C.G. limits.
- He should practice stalls and stall recovery from simulated landing approach conditions; speeds, power settings, banks angles. etc. He should learn to recognize the onset of the stall, and practice immediate recovery. (forward stick to break the stall, add power to gain speed and control response, and level the wings for added lift.)
- Landing approach stalls should be practiced at C.G. conditions up to but not exceeding the aft limits of the air-

craft. Practice should include stalls in a medium to steep banked turn with inside rudder, the conditions which might be encountered on a 'tight turn to final". Only through practice can a pilot gain the experience necessary to make a safe stall recovery with a minimum altitude loss and with a maximum of controllability. *Adjusting Pitch Trim:* The pitch stability of the RV was designed to be achieved by a small positive wing incidence angle and a stabilizer incidence angle of zero. Ideally, the elevator trim tab should be in neutral position or slightly up (nose down) in cruise flight conditions and mid-C.G. range loadings. The leading edge of the elevator counterbalance should be slightly higher (approx. 1/4" for RV-6 & 8, and 3/8" for RV-4) than the stabilizer in these conditions.

Trim tab positions can be checked either by viewing from a chase plane, by marking of the trim control in the cockpit, or by leaving the trim control in the "cruise" position throughout the landing, and then visually checking its position after the flight.

Adjustment of the stabilizer incidence angle is recommended if the cruise position of the trim tab is more than 10 degrees up at cruise. The only correction for this is altering the incidence angle by repositioning the forward spar of the stabilizer up or down. The amount of re-adjustment needed will be determined by trial and error. Add or subtract spacers (washers) under the bolts which attach the front stabilizer spar to the fuselage. By adjusting one washer thickness (1/16") at a time, the desired trim can be attained. Repositioning the stabilizer will require an alteration of the stabilizer root fairing, so should only be attempted after careful testing to determine the necessity.

DIRECTIONAL (YAW) STABILITY:

An off-center skid ball, and/or a roll tendency that increases with speed are common for many new airplanes. Small trim adjustments should be made so the airplane flies straight and true in a stick free mode.

To test directional stability and trim, establish and hold level flight. Remove your feet from the rudder pedals. If the skid ball is does not remain centered, rudder trim will be needed. Apply rudder as necessary to center the ball and determine whether "right or left" trim will be needed. A fixed wedge type trim tab can be added to the rudder. Unlike tabs which stick out past the trailing edge, these do not alter the planform profile of the control surface, yet are very effective. A temporary tab of this type can be made of wood, sawed into a wedge about 3/8" at the thick edge and 1 1/4 to 1 1/2" wide. This can be temporarily taped on to the rudder trailing edge near bottom and adjusted simply by trimming the length. Attach to the side of the rudder opposite that of the rudder pedal effort needed to center the ball. It may take several flights to determine the exact size. Then the temporary wedge can be replaced by a wedge made of machined aluminum, plastic, or sealed wood, and attached with flush pop rivets.

Destabilizing effects of wheel fairings and gear leg fairings. When checking directional trim, don't overlook the effect of gear leg fairing mis-alignment. Though the gear leg fairings have a relatively small area, and are located near the center of rotation (C.G.-Center of lift) of the aircraft, they can have a profound effect on directional trim. This is because the destabilizing influence of are forward is greater than the stabilizing effect of area aft. It is a good idea to check directional trim with and without the gear leg fairings in stalled. If there is more un commanded yaw with the gear leg fairings installed, their alignment should be altered until the yaw is no greater than without them. Then final trim can be accomplished with a rudder tab. Re-aligning the gear leg fairings can be unpleasant because of the need to alter (re-mold) the intersection fairings at the wheel pant or fuselage. However, we cannot emphasize to strongly the amount of yaw which can be caused by as little as a 1/4" trailing edge misalignment of a gear leg fairing. Simply adding an oversize trim tab to the rudder is not acceptable. While it would correct adverse yaw, it could also cause spin recovery to be adversely affected.

Directional check:

Directional (yaw) stability is tested by establishing and holding level flight. Apply hard rudder to yaw the airplane in one direction and quickly release the pressure, keeping both feet off the pedals. The airplane should immediately return to aligned flight. In RVs, the yaw correction is so fast that an overshoot to yaw in the opposite direction will occur. Usually, 4-6 overshoots of decreasing intensity will occur before the yaw will dampen out. (An overshoot is an excursion to either side. A complete yaw cycle comprises 2 overshoots.)

Direction stability in a typical RV aircraft is quite positive. When a hard yaw is induced, the dampening cycles are rather short period—almost difficult to count fast enough. If a slow damping cycle is experienced and the overshoot count is high, it could be evidence of an improperly formed rudder trailing edge. Check to see that the trailing edge meets design and construction criteria. (see rudder drawings and the appropriate Figure in Section 6.) Rudder control is affected by blunt trailing edges in a manner similar to the elevators.

LATERAL STABILITY FLIGHT TEST;

Lateral check: Trim pitch control (elevator trim) for level flight and hold a heading with the rudder (if aircraft not in directional trim). Also, if an aileron trim system is installed, it should be set at center or neutral. Release the stick and note any roll tendency or "heavy wing". There is a good chance that any given RV will be out-of-trim laterally, requiring a small fixed tab on one of the ailerons to maintain neutral stability. However, remember that a fixed trim tab provides complete correction at only one speed, and should be set for the prevalent speed, usually cruise. Varying fuel loads in the wing tanks can either offset lateral stability or to a limited degree, be used to correct a trim imbalance. When checking aileron trim, right and left side fuel loads should be near equal.

Aileron trim is traditionally achieved through use of trim tabs as described for elevator and rudder trim. Because of the structure of RV ailerons, another means of trim adjustment is possible. This is through alteration of the aileron trailing edge bend radius. This does not apply to the RV-9/9A ailerons. The theory behind this phenomenon is thus:

The high pressure air on the lower surface tends to flow up around the trailing edge into the lower pressure on the upper surface. The size of the trailing edge radius affects these flow patterns and thus causes the aileron to lift or drop because of the "jet" effect of the attached airflow being deflected upwards. Altering just one aileron will have the same general effect as adding a trim tab.

Before installing trim tabs or altering the trailing edge of the aileron as described below, check aileron alignment carefully. If the vertical alignment of the ailerons differs visibly (i.e.: the nose of one aileron is noticeably higher or lower than the other when the ailerons are in neutral) this should be corrected before further measures are taken. This may require installing new A-406 and A-407 brackets on the aileron in a slightly different position than the original ones.

Experience has shown that roll trim can be achieved by decreasing or "tightening" the trailing edge of the aileron on the "light" wing - the one coming up as the airplane rolls. If the trailing edge is too blunt, squeezing it tighter (with just your fingers) along the length of the aileron can have an effect. If this is not completely effective, a mechanized method may be needed.

One method is to cover the jaws of a hand seamer with tape and use it to squeeze the trailing edge. However, even when being very careful, the ends of the seamer tend to leave small dents in the skin. Another method is that of using clamping blocks; small boards such as 1x2s place on top and bottom of the trailing edge and squeezed together with C-clamps., Regardless of the method used, the result should be a barely perceptible change in shape, as gauged by sighting down a straight edge laid on the skin. Small variations in shape can have very noticeable affects on control. Fly the airplane to gauge the result. Several such trial-and-error attempts may be needed to achieve the desired results. If an over-correction occurs, it can be corrected in two ways.

- The opposite aileron's trailing edge can be reduced slightly in the above manner. This is OK providing that the aileron control forces have not increased too much. As the trailing edge radius decreases, stick force increase. Also, the skins will crack if squeezed too tight.
- Expand the trailing edge radius, which has been squeezed too much. This can be achieved in an unlikely manner, with a board and a hammer. Yes, by holding a length of board such as a 2x2 butted up against the trailing edge and tapping the board along its length with the hammer, the radius can be "opened" up slightly—enough to have an effect on trim. But, be very careful.

If adjusting the trailing edge radius does not provide the desired trim effect, a trim tab wedge probably will. If the out-of-rig condition is too extreme to be corrected by a trim wedge of over 6 inches in length, there is a serious construction or rigging anomaly which must be identified and corrected. Contact the engineering staff at Van's Aircraft for possible assistance.

If the aircraft is equipped with an aileron trim control system, it can be used in lieu of fixed tabs. However, it is suggested that fixed trim methods be used to offset destabilizing effects of airframe irregularities, and that cockpit adjustable trim controls be used to offset variable loads such as fuel and passengers (for side-by-side seating).

Large trailing edge radii on the ailerons can cause a condition known as "aileron snatch" which is generally similar to the "hunting" tendency mentioned for elevators and rudders with blunt trailing edges. However, ailerons are different than the elevator or rudder because there are two of them, interconnected and operating opposite each other. The "snatch" is recognizable by the tendency of the ailerons to seek a neutral (stick free) point to one side or the other of center. Aileron snatch causes an uncomfortable control situation for the pilot because the control stick must be held in the center. Movement in either direction will initially be self driven for the first bit of travel, then normal loads begin to build as with additional stick deflection. When moving the stick from one side to the other, an area of control force reversal will be experienced when passing through center.

Stick free, aileron snatch will result in a rolling tendency. A fixed trim tab will not correct this as it would just push the ailerons over center to one side, rather than returning them to center as desired. Correcting aileron snatch can usually be accomplished by reducing the trailing edge shape and radii to that shown on the plans.

After the lateral control trim has been completed, another test can be made. Establish a medium bank of 20-30 degrees and release the stick. If the wings return to a level attitude, the airplane has exhibited positive lateral stability. If the angle of bank remains the same stick free, the aircraft has neutral lateral stability. If the bank angle continues to increase when the stick is released, the lateral stability is divergent; a potentially dangerous condition.

Neutral lateral stability is common for RVs because of their short span and low dihedral angle. Negative or divergent lateral stability is more likely to occur in aircraft with long wings and/or insufficient vertical control surface area.

Sometimes stability investigations can be confusing; situations where unlikely or unexpected factors cause seeming unrelated symptoms. One instance comes to mind where a certain RV exhibited asymmetric roll rates and control force. Naturally, the investigation centered on possible wing twist or wing rigging (we checked for unequal incidence angles, or aileron abnormalities.) The cause was eventually found to be a rather severe twist in the horizontal stabilizer which imparted a constant rolling moment. So, a lot of aileron trim was needed just to maintain wings level, and the stabilizer induced roll force either added to or subtracted from the rolling input of the ailerons. Corrective action in that case was construction of a new stabilizer.

This ends our presentation on stability and control. However, it by no means is a complete thesis on the subject. Rather, it is deemed sufficient to help an RV pilot evaluate his airplane and make corrections to minor abnormalities. A more authoritative and thorough dissertation can be found in the book FLIGHT TESTING HOMEBUILT AIRCRAFT by Vaughn Askew. This text is highly recommended and is available from various sources including the Io-

wa State University Press, and Van's Aircraft, Inc.

STALL TESTING:

We mentioned testing of mild, power off stalls during the initial test flight. After more confidence in the aircraft is gained, the pilot should proceed to perform stalls entered from all anticipated flight conditions. All types of stalls should be practiced; departure (climbing) stalls, approach (gliding) stalls, stalls with varying degrees of bank, stalls at minimum and maximum weights, cross-control stalls, and accelerated stalls. Stalls at every imaginable attitude and from every imaginable entry condition. The object is not only to gain familiarity with stalls from every conceivable flight condition, but to become comfortable with recognition of and recovery from these stalls. Not comfortable in the sense of being careless, but comfortable in the sense of being confident in your ability to control any situation. Practicing many and varied stalls will heighten your awareness of attitudes and flight conditions to be avoided because of the severity of the stalls which might result from them.

Except for accelerated stalls and secondary stalls, approach each slowly (a deceleration rate of 1 mph per second is recommended) while correcting for P-Factor (for power stalls) with the rudder. Allow the speed to bleed off until you feel a slight buffet. Note the airspeed and recover with a smooth forward movement of the stick as power is added. Maybe simply relieving back pressure on the stick when the stall occurs would be sufficient for your airplane. Stalls entered from steep bank or climb attitudes will require more aggressive recovery control application. But remember, at some loading conditions, an RV has light elevator forces, and over controlling can easily occur, and secondary stalls can be encountered.

After gaining familiarity with stalls with instant recovery, delayed recovery can be practiced. Starting with wings level, 1 G stalls, delay the recovery by a count of 1,2,3, etc. seconds. The only purpose of this is to gain further experience with handling qualities in extreme conditions and to determine your ability to control the aircraft in a prolonged stalled mode. While one should always recover immediately at the first warning of an accidental stall, intentionally holding the airplane in a stall will provide the pilot with a greater experience base.

Another bit of wisdom to remember is that the airspeed systems can be inaccurate at the high angles of attack experienced at stall speeds. Indicated stall speeds can be in error by 5 mph, possibly even more. However, the readings are relative and you can believe that your gauge will indicate the same stall speed consistently, if the stall is approached at the same rate and G-load every time.

While practicing stalls, the pilot is not only gaining familiarity with that specific airplane for his piloting benefit, but is also evaluating that airplane's stall characteristics against an ideal. The ideal is that when a stall is encountered, the nose tends to lower, or can easily be lowered by an easing of stick back pressure or by a forward stick pressure. In most RVs, there is little advance stall warning in the form of pre-stall buffet. The buffet which does occur does so within just a mph or two of the fully developed stall. The other characteristic being evaluated is a laterally uniform stall—or what is often called a straight forward stall. Airfoil irregularities, wing incidence misalignment, and wing twist can cause one wing to stall at a higher speed than the other. This obviously will cause one wing to drop when the stall occurs. This is not uncommon for RVs, and if the extent of wing drop is slight, no more than 10-15 degrees, it is of little consequence. Sometimes an asymmetric stall can be corrected by altering the angle of incidence of one wing by re-drilling off-center an oversize rear spar attach hole. This method will have limited success because structural constraints limit the extent of oversize hole which is acceptable. Consult with service personnel at Van's Aircraft before attempting this.

Another cause of asymmetric stall is airfoil irregularity caused by landing lights in the wing leading edge. The "lip" which usually occurs between the wing skin and the plexiglass lenses causes a disrupted airflow which acts as a spoiler, reduced lift, and causes that wing to stall prematurely. If this is suspected, smooth tape can be placed over the offending edges before re-testing. If this is found to be a factor, a re-work of the landing light installation could minimize the misfit and thus the stall asymmetry. A small stall strip on the opposite wing can also be used to achieve a balanced stall. Very few RV pilots have added stall strips to their wings. Whether this is because there is no need or because of lack of knowledge about the potential benefit, we do not know.

SPIN TESTING:

"A spin is a condition in which an airplane rotates because one wing is deeper in stall than the other. A spin is a highly complex dynamic maneuver that is still not fully understood, even by the experts."

Flight Testing Homebuilt Aircraft, by Vaughn Askew.

Accidental spins can result from a variety of conditions in which asymmetric wing lift is induced. Spins normally are caused by improper rudder usage coupled with a stall (including accelerated stalls) Out-of-coordination rudder produces a yaw which in turn causes asymmetric wing lift which drives the rotation. Avoid these conditions, and accidental spins won't happen. Since this utopian condition cannot be guaranteed, a degree of spin investigation training is suggested.

Intentional spin entry should be initiated from a power off stall with full rudder in one direction and full elevator following the initial stall break. Typical spin behavior for an RV is that if control pressures are released immediately following spin entry, recovery will be automatic and almost immediate—no more than 1/2 spin revolution. If spin rotation is held for approximately one full revolution, recovery can be accomplished quickly through application of anti-spin control (opposite rudder, stick centered). If pro-spin controls are held until two full revolutions have been completed, the spin will be fully developed. Recovery techniques will vary.

For RV-3s, 4s, and 8s, the most effective recovery technique is as follows:

- Power off.
- Elevator centered. (or stick free)
- Full opposite rudder.
- Recover from dive as soon as rotation stops.

Recovery time (time to stop rotation) will vary depending on C.G. position and other factors. Step #2 is best accomplished "hands-on stick" rather than stick-free because while in spin rotation, the outside aileron will sometimes float up, thus driving the stick out of center.

(As an example, here is what we found when spin testing the prototype RV-6. Remember, this is one individual airplane! Our results and yours may vary significantly.)

Testing was performed up to the limit load (1375 lb. aerobatic gross) and C.G. (25% aft of leading edge) with satisfactory recoveries being easily affected.

For prototype RV-6 and RV-6A aircraft, spin characteristics and recovery procedures were found to be as follows:)

The prototype RV-6 & RV-6A aircraft exhibited good spin resistance. Forceful pro-spin (full up elevator and full rudder) control pressures were necessary to induce a fully established spin. Good spin recovery was evident during the first two rotations. Simply releasing the controls during the 1st rotation stopped the spin, and opposite rudder and forward stick caused a quick recovery during the second rotation. After two turns, the rotation rate increased and stabilized between 3 and 4 turns with a high rate of rotation of about 180 degrees/second. Once past approximately 2 spin rotations, the spin had stabilized and if the controls were freed, the RV-6 would continue spinning until anti-rotation control inputs were applied. One reason for this is that in a fully developed spin, the elevators float up and remain there hands-off. Recovery procedure consists of the following:

- Power to idle.
- Apply full opposite rudder, (opposite the direction of rotation)
- Center the ailerons and elevator. (Because of the up elevator float, forward stick pressure is needed to center the elevators.
- Hold the above control positions until rotation stops, then use the elevator to recover to level flight. 1 1/4 to 1 3/4 rotations are usually required for rotation to stop.

Because of the high rotation rate and the positive (rather than automatic) spin recovery technique required, Van's Aircraft Inc. recommends that pilots of RV-6/6A and RV-7/7A aircraft limit their intentional spins to two turns or less, and that recovery from incipient accidental spins be initiated immediately upon recognition. **The RV-9/9A is not intended for spins at all.** Learn the conditions that lead to accidental spins, how to recognize the onset of a spin, and how to immediately and subconsciously stop an incipient spin. Then, fully developed spins, and the need to recover from them, will become less probable.

Spin testing, like other forms of limit testing, should only be attempted while wearing a parachute and after memorizing escape procedures. Memorize anticipated recovery techniques and act deliberately and calmly throughout the entry and recovery from the spin. Perform intentional spins in progressive steps, starting with immediate recovery, recovery after 1/2 turn, recovery after one turn, etc. Also, begin spin testing with forward C.G. loadings and proceed to more aft loadings as satisfactory recoveries are experienced.

All homebuilt RVs should be individually tested because small variation in configuration can sometimes greatly affect spin characteristics. This is particularly true for any variations in vertical surface areas forward of the aircraft center, and for changes which may affect airflow over the forward surfaces and/or the tail surfaces. For example, spin testing of prototype RVs has shown that spin characteristics differ noticeably with wheel and gear leg fairings installed or removed. The vertical area of these components, located forward of the center of rotation of the airplane, causes a destabilizing effect that degrades spin recovery. There are after-market gear leg fairings being marketed which are wider than those tested and supplied by Van's Aircraft. Because spin testing has shown that small changes such as this can cause a noticeable change in spin recovery, builders are advised to use caution when making changes such as this to their RVs.

One often cited example of how small alterations can affect spin characteristics is the Beechcraft Musketeer. The early production airplanes had an engine cowling with a rather abrupt transition (squared off) from its top to side surfaces. A later version had a reshaped cowl that had a smoother transition between the top and side cowl surfaces. The result was that while in a spin mode, the cross flow over the cowl now produced more lift and held the nose up, inhibiting spin recovery. As with all other areas of testing; don't make any assumptions! Recommended spin test altitude is between 6,000' and 8,000' AGL to allow plenty of altitude margin for recovery.

Inverted spins were not tested because the prototype test aircraft were not equipped for inverted flight.

Van's Aircraft Inc. does not consider spins to be a recreational aerobatic maneuver, and recommends that they not be casually undertaken.

Propeller Evaluation: Your propeller should load the engine sufficiently in level flight that the engine, at full throttle will not exceed its redline limit. Nor should the engine exceed redline rpm during takeoff. Sometime these requirements are hard to meet with the same prop (see the discussion of fixed pitch props in Section 11.)

Airspeed Calibration: Air speed indicator systems, particularly in homebuilt airplanes, are often inaccurate. Sometimes very inaccurate! Note that we refer to the air speed indicator system, not just the air speed indicator instrument itself. The system comprises five components: Dynamic pressure source (pitot tube), instrument, static pressure source, air lines, and an indicator.

The location of the pitot tube relative to the air pressure areas around the airframe is of great importance. The ideal location is one where the true air velocity relative to the airframe can be measured. The pitot tube cannot be located at any point on the fuselage because it is within the influence of the propeller disc. The only exception would be mounting it above the tip of the vertical stabilizer. This location is fine except for high angle of attack flight, as in landing attitude, where fuselage and propeller airflow disturbances cause significant inaccuracies.

The ideal pitot location would seem to be forward of the wing, in undisturbed air. But, within the first 6 to 12 inches forward, the airflow is already affected by the approaching wing, and this location results in pressure errors as much as 10% high. It is necessary to locate the pitot tube least 1/2 the wing chord length forward of the leading edge to eliminate pressure errors. This is why we see the large pitot “stinger” on factory prototype and test airplanes.

Since long leading edge pitot tubes are impractical, a compromise position is sought. This usually becomes some experimentally derived point under the wing. The pitot tube shown on the plans is located for easy manufacture and maintenance, and has proven to be a quite accurate pressure source. Use of pitot tube designs or locations other than this could result in less accurate airspeed readings.

The airspeed indicator itself could be out of calibration due to age or manufacturing inaccuracies. Any instrument repair shop can check and re-calibrate air speed indicators. However, one primary object of this sub-chapter is to alert pilot/builder that an accurate airspeed indicator does not in itself guarantee correct indicated airspeed readings.

The static source must be located in an area of neutral or ambient pressure; an area where the shape of the airframe has caused the airflow to be neither above or below atmospheric pressure. Cabin air pressure is not neutral as might be thought. Canopy and door air leaks, air vents, etc. cause cabin pressure to vary enough to result in errors of 5 mph or more if used as the air speed static source. Production aircraft often use an experimentally located static source point on the aft portion of the fuselage where airflow pressure recovery provides atmospheric pressure. The static opening at this location is also less prone to ice formation than elsewhere. The recommended RV-static source point and system components is shown in an earlier chapter of this Construction Manual or on the drawings.

The fourth system component is the lines for both the pitot and static air. Pressure requirements for either are minimal, so practically any aluminum, plastic, or rubber line can be used. Airtight sealing of the lines is important because any leakage can compromise an otherwise accurate system. One method of checking a pitot system for leaks is just a clear plastic tube partially filled with water and slipped over the pitot tube. Elevating the open end of the tube will cause the water to flow inward (but not into the pitot tube) and build a slight pressure in the system. If the lines are airtight, the water level will remain the same. If the water level slowly returns to a balanced condition, then the system has a leak.

Such an airspeed indicator system installed in a RV should provide reasonably accurate airspeed readings; certainly accurate enough for initial test flying. Most pilots will want to calibrate their airspeed indicator readings for the purpose of documenting performance data and performing limit testing. One simple method of doing so is to fly alongside another airplane and compare airspeed readings. This would be fine IF the other airplane's airspeed system was guaranteed to be accurate. But, it probably isn't, even though it may be an expensive, late model airplane.

We recommend performing the airspeed calibration through time/distance calculations. All that is needed is a ground course of known distance, preferably about 5 miles in length, and a stopwatch. Fly both directions over the course at a steady indicated speed, power setting, and altitude. Time each run with the stopwatch. Compute the speeds for each run, add them together, and divide by two to get the average ground speed. Do not calculate the average speed from the total distance divided by the overall time. The effect of any wind will result in an erroneously low speed.

A sample calculation is shown at the end of this section. We have intentionally factored in a strong wind to illustrate the effect of averaging individual speeds rather than computing speeds from the elapsed round trip times. (Performing speed calibration testing during windy conditions is usually futile because the turbulence associated with winds will make it impossible to maintain steady airspeed and get accurate results.)

Use a flight calculator to compute true indicated airspeed from the indicated airspeed reading (factored for temperature and altitude) and plot this speed against the calculated ground speed. Repeat this procedure for indicated airspeeds vs. timed ground speeds at 10-20 mph intervals from near stall speeds to max.cruise speeds. From this, an airspeed calibration curve can be drawn and corrections made for any indicated airspeed.

An Alternate Calibration Method: Loran and GPS have given the test pilot another valuable tool in more ways than intended. Nearly all lorans provide a ground speed readout. For rough speed checks, this groundspeed readout can be recorded for two way runs at given power conditions. However, the groundspeed readouts usually fluctuate over a range of several mph, and are therefore not a precise calibration tool. However, lorans also provide continuous position reports in the form of Lat./Lon. coordinates. These coordinates can be used just like visible ground markers for a speed check course. All that is required is that the speed calibration runs be made on North or South headings. Each degree of latitude equals 60 nautical miles. Thus, every minute of latitude equals 1 nautical mile and each 1/10 minute (finest reading on most lorans) equals 1/10 nautical mile. Runs can be of any length desired. 10 nautical miles is a convenient figure, corresponding to 10 minutes latitude. Runs of this length are more accurate than short runs because any variation in time starting or stopping the watch is averaged over a longer time. For instance, if the course were only a mile long, a 1/2 second error in timing a 200 mph run would cause an error of over 5 mph. The same 1/2 second error made in timing a 10 mile run would cause an error of only 0.5 mph.

Some of the advantages of using loran (GPS) for speed checks is that the altitude is not important. The invisible mile posts are at 8,000' altitude as well as at the surface. Thus, speed checks can be made at normal cruise altitudes where full throttle can be maintained for extended time periods, and where smooth air is available at almost any time. Indicated airspeeds can be checked against timed ground speeds and against loran ground speed readouts.

An actual sample of an RV-6A test flight and computations from is included at the end of this section.

GPS tests for airspeed calibration

GPS is a more valuable tool for use in calibrating airspeed systems than is loran, primarily because of its greater accuracy and more consistent ground speed read outs. GPS ground position reports could be used for speed computations as described above for loran. However, GPS ground speed reading have been found to be so accurate that they can be used interchangeably with zero wind true air speed. Thus, if the air mass was perfectly stable (no wind), GPS ground speed and true airspeed would be the same. However, there is almost always some wind, particularly at altitudes where convective turbulence is not a problem. Thus, flying a multiple heading pattern is an easy and accurate means of canceling wind effect from ground speed read outs.

The commonly accepted procedure is to fly a box shaped pattern on the prime headings of 90, 180, 270, and 360 degrees. (fly heading rather than track) Record the ground speed readings for these heading and compute the average. While this would seem a simple procedure, carefully flying is necessary to arrive at accurate figures. The airplane must be flown precisely and the atmosphere must be very stable (no vertical movement). Even at higher altitudes where the air is generally smoother, there is often minor turbulence, wind shear, or waviness which makes it difficult to hold a constant altitude and indicated air speed. For example, it is common to experience smooth waves in the atmosphere, with low vertical velocities—you can't feel any bumpiness but you can see the altimeter (or VSI) alternating, up and down. Under these conditions, constant trim changes, and thus airspeed changes, are necessary to maintain level flight altitude. A simple calculation showed that a 100 fpm vertical component would cause a true airspeed variation of about 2.5 mph in an RV. Thus, flying from the positive to the negative phase of the wave would show a 5 mph variation.

Similarly, assuming that the atmosphere were perfectly stable, when flying at 200 mph, a pilot error of 1/2 degree pitch attitude will cause a 150 fpm climb or descent rate and several mph speed variation. Thus, great care must be taken to find smooth air and fly precisely in order that truly accurate speeds be recorded. It is a good idea to fly the speed box more than once to check consistency and obtain averages if speed variation occur.

LIMIT TESTING

Limit testing of a homebuilt, particularly a high performance one such as the RV, is an endeavor to be approached with caution and preparation. What the pilot is doing is challenging the airframe to withstand the limit loads he is imposing on it, or in a sense, daring it to fail. Most homebuilder/pilots are not daredevils and would just as soon not do limit testing. However, as it is the best available means of verifying design limits, it must be done if all future flights are to be made with confidence. With proper preparation, limit testing need not be as frightening and dangerous as it might appear. Particularly during this phase of testing, the pilot should wear a parachute and familiarize himself with its operation. Also, emergency egress of the airplane should be reviewed and memorized. Limit testing should be done at altitudes of at least 5000 ft. above ground, preferably around 8,000 ft. Along with careful planning, altitude can be a lifesaver. While the thought of structural failure or loss of control is not at all appealing, it is far better that it be encountered during controlled testing than under conditions where no options exist (low altitude, no parachute, etc.). By assuming and preparing for the worst, limit testing can be done with reasonable confidence. Flight testing of the RV prototypes proved to be routine and uneventful. With thoughtful construction and preparation, testing of homebuilt RVs should be the same. Limit testing categories include FLUTTER TESTING, G-LOAD TESTING, and SPIN TESTING. (Spin testing is also classified under Stability testing, so has been included in that section of this chapter)

FLUTTER TESTING

Flutter in an aircraft structure results from the interaction of aerodynamic inputs, the elastic properties of the structure, the mass or weight distribution of the various elements, and airspeed. The word "flutter" suggests to most people a flag's movement as the wind blows across it. In a light breeze the flag waves gently but, as the wind speed increases, the flag's motion becomes more and more excited. It is easy to see that if something similar happened to an aircraft's structure the effects would be catastrophic. In fact, the parallel to a flag is quite close.

Think of a primary surface with a control hinged to it (e.g., aileron). Imagine that the aircraft hits a thermal. The initial response of the wing is to bend upwards relative to the fuselage. If the center of mass of the aileron is not exactly on the hinge line, it will tend to lag behind the wing as it bends upwards.

In a simple, unbalanced, flap-type hinged aileron, the center of mass will be downward. This will result in the wing momentarily generating more lift, which will increase its upward bending moment and its velocity relative to the fuselage. The inertia of the wing will carry it upwards beyond its equilibrium position to a point where more energy is stored in the deformed structure than can be opposed by the aerodynamic forces acting on it.

The wing “bounces back” and starts to move downward but, as before, the aileron lags behind and is deflected upwards this time. This adds to the aerodynamic down force on the wing, once more driving it beyond its equilibrium position and the cycle repeats.

At low airspeeds, structural and aerodynamic damping quickly suppresses the motion but, as the airspeed increases, so do the aerodynamic driving forces generated by the aileron. When they are large enough to cancel the damping, the motion becomes continuous. Further small increases in airspeed will produce a divergent, or increasing, oscillation, which can quickly exceed the structural limits of the airframe. Even when flutter is on the verge of becoming catastrophic, it can still be very hard to detect. What makes this so is the high frequency of the oscillation which is typically between 5 and 35 HZ (cycles per second). It will take only a very small increase in speed to remove what little damping remains and the motion will become divergent rapidly.

Flutter testing of factory prototypes has resulted in establishing a true <u>and</u> indicated NEVER EXCEED SPEED (Vne) of 210 statute mph for the RV-3,4 and RV-6/6A, 230 statute mph for the RV-7/7A/8/8A. and 210 statute mph for the RV-9A. This speed was determined through flutter testing at a speed of 20 mph above Vne. (FAA certification criteria require flutter testing up to Vne plus 10% or about 20 mph) The flutter testing performed consisted of exciting the controls by sharply slapping the control stick at various speed increments up to this level. Under all conditions, the controls immediately returned to equilibrium with no indication of divergent oscillations indicative of flutter. This testing was performed on factory prototype aircraft, and the flutter free flight operation of subsequent amateur built RVs has substantiated published Vne.

The “slap-the-stick" method of exciting the controls for flutter testing is potentially dangerous and requires a very skilled pilot trained to recognize the subtle control responses which indicate the onset of flutter. For this reason, it is suggested that amateur builders do not perform flutter testing of their RVs. Rather, the airplane should be constructed in strict conformity to the plans with particular attention paid to the control system--- trailing edge radii, skin stiffness, control linkage free-play, and static balance in particular. Maintaining conformity with the prototype (plans) will provide an adequate level of assurance against control surface flutter. Any design changes to the control surfaces, control system, or primary structure could invalidate the testing which has been done, and require that testing be re-accomplished.

G-LOAD TESTING

As with flutter testing, G-load testing should be conducted systematically, progressing gradually to higher and higher levels. 6 G's is the highest level recommended in testing. This is the maximum load the structure is designed to be able to withstand indefinitely. While the actual calculated breaking strength is 9 G's, the structure is designed to withstand this load for only 3 seconds. Approaching this load level could permanently weaken the structure even if failure does not occur. The margin between 6 and 9 G's is reserved to compensate for the effects of airframe deterioration through aging, fatigue, material flaws, or construction errors. G-loads of over 6 should never intentionally be applied to an RV structure.

<u>MAXIMUM G-LOAD:</u>

The structure of the RV-4 and RV-6/6A have been designed to withstand aerobatic design loads of plus 6 Gs and minus 3 Gs at an aerobatic gross wt. of 1375 lb, or 1600 lb for the RV-7/7A/8/8A. The RV-9/9A structure had been designed to withstand utility design loads of +4.4/-1.8G at a utility gross weight of 1600 lbs. Flight testing to the positive G limit can be done by putting the airplane in a tight turn and applying elevator back pressure. Do this progressively; increasing the load by 1G increments until the load limit is reached. Between each loading acceleration, relax and look over the airplane. Move the controls to assure that everything is normal.

For operational gross weights above this figure, aerobatic maneuvers should not be performed. This also assumes that the RV was built in strict conformity with the plans. Any variation in materials used, dimensions of primary structural parts, or workmanship standards, can cause a loss of strength and cause the actual limit load to be less than the design limit load.

The 3 G design limit for negative loads also has a built-in 50% margin. Thus the breaking strength would be -4.5 Gs.

If the RV being tested is equipped with inverted fuel and lubrication systems, negative G testing should also be done. A parachute should be worn while conducting load testing.

<u>MANEUVERING SPEED:</u> 134 mph statute for the RV-4 and RV-6/6A, 142 for the RV-7/7A8/8A, 118 for the RV-9/9A. By definition, maneuvering speed is the maximum speed at which full and abrupt controls can be applied. It is also the minimum speed at which limit G-load can be produced. Thus, at any speed in excess of this, full control application could result in G-loads in excess of design limits. The maneuvering speed is function of clean (no flap) stall speed. For utility category aircraft like the RV-9/9A, it is 2.1 (the square root of 4.4) x stall. For aerobatic category aircraft, it is 2.45 (the square root of 6) x stall. Because RVs have low stall speeds, maneuvering speed is low relative to cruise and Never Exceed Speed.

Based on the same formula used to determine maneuvering speed, full control application at Vne would produce a G-load of about 15. From this it should be very obvious that at any speed above maneuvering speed, the pilot becomes the limiting factor: he can impose destructive loads on the structure through excessive control application. ***Because of its high ratio of top speed to stall speed, the RV is more susceptible to pilot-induced overstresses than are most other contemporary aerobatic airplanes.***

GROSS WEIGHT: See Section 14.

AEROBATIC OR UTILITY GROSS WEIGHT: See Section 14.

FLAP SPEED: On the RV-4/6/6A/7/7A/8/8A, 110 Statute for 20º and 100 mph statute for full 40º flap deflection. On the RV-9/9A, it is 100 smph for 15º and 90 smph for 32º.

AIRSPEED INDICATOR MARKINGS

AEROBATICS

SPEEDS IN STATUTE MILES PER HOUR	***RV-4***	***RV-6/6A***	***RV-7/7A/8/8A***	***RV-9/9A***	***RV-10***
Bottom of White Arc: (Approx. Indicated stall speed with full flaps)	54	55	58	49	60
Top end of White Arc: (Max. speed with full flaps)	100	100	100	90	100
Bottom of Green Arc: (Approx. indicated stall speed without flaps)	58	59	64	56	70
Top end of Green Arc: (Max. structural cruise speed)	180	180	193	180	180
Blue Line: (Maneuvering speed-Max. permissible speed at which full control can be applied. Speed at which full elevator control would impose loads exceeding limits)	134	134	142	118	144
Yellow arc: (caution range, to be flown only in calm or light turbulence conditions)	180-210	180-210	193-230	180-210	180-230
Red Line: VNE (IAS and TAS: Maximum permissible speed under any condition)	210	210	230	210	230

Note: The RV-9/9A is NOT designed or intended for aerobatics.

Note: Aerobatic maneuvers as defined by the FAR's include bank angles greater than 60 degrees relative to the horizon and nose-up/nose-down pitch angles of 30 degrees relative to the horizon. These maneuvers must be performed above a minimum altitude of 1500 feet AGL and all participants in the aircraft must wear a parachute.

RV airframes are stressed for aerobatics up to a gross weight of 1050 lb.for the RV-3, 1375 lb for the RV-4/6/6A, and 1600 lb. for the RV-7/7A and the RV-8/8A with the "Dash One" wing (included in all RV-8/8A kits shipped since January, 2001.) Earlier RV-8/8As with the original wing have an aerobatic gross weight of 1550 lbs.

This means that they have design strengths of 6 positive and 3 negative Gs (plus a 50% safety factor) at up to this weight. The key word is WEIGHT. RV structures have a certain amount of strength and are capable of carrying a given load at given G load. If the weight increases, so does the stress. As the empty weight increases, the useful load decreases —less fuel and pilot/passenger load can be carried within the aerobatic weight limit. For this reason, a heavy 2-seat RV may become a single place aerobatic airplane because it cannot carry two people and remain under the aerobatic gross weight limit. We expect that the empty weights of many RV-4s and RV-6/As will be over 1050 lbs. because of optional equipment installed. These will definitely be single place aerobatic airplanes. Some RVs have been built with such high empty weights that when flown by a pilot weighing much over 200 lb., are no longer structurally qualified to perform aerobatics at all. Check the specific aerobatic gross weight given in Section 14. Always remember, RVs are ***not*** indestructible. Like all other airplanes, they have been designed with finite limits which must be observed. As a homebuilt, any individual airplane may have different limits which in all probability will be lower than design limits.

For or those wishing to do aerobatics in their RVs, aerobatic testing should be done during the later portion of the flight test period. We suggest that aerobatics be approached cautiously, and only after becoming thoroughly familiar with control responses, handling qualities, and performance capabilities. The pilot should also have received formal aerobatic training in other aircraft. Most RVs are capable of easily performing basic aerobatic maneuvers. This capability is due to their relatively high power loading and to their aerodynamic cleanliness which produces the speed (energy) needed. But, because of this, excessive speed build-up can occur very quickly, and should be a primary concern when attempting and practicing aerobatics. As an example, one does not enter a split-s maneuver from anything near cruising speed (like you see fighters doing in the old movies) because there is no way to complete the maneuver without exceeding speed and/or G-Load limits. The safe entry speed for a Split-S is around 100-110 IAS. The point is that RV aerobatics are not the same as Pitts or Citabria aerobatics. Speed builds very fast when pointed downhill.

Elevator stick forces are relatively light, so it is not a good idea to turn the controls over to a passenger for the purpose of aerobatics. Nor is it a good idea to apply control forces similar to those you may have become accustomed to in some other aerobatic airplane, say, a Citabria or a Stearman. Over stressing could easily occur. This is why you should be thoroughly familiar with the flying and handling qualities of your RV before attempting aerobatics. Because of its light controls, the RV is a pilot-limited airplane. In other words, it is the pilot's responsibility to avoid over stressing the airplane.

Aerobatic Entry Speeds: Refer to the section on maneuvering speed when contemplating aerobatics. Remember that the maneuvering speed is defined as the highest speed at which full and abrupt controls can be applied without exceeding the design strength of the airplane. This does not mean that it is the highest permissible aerobatic entry speed. It just means that for any speed above the maneuvering speed, control inputs must be limited to less than full—and less than that needed to produce 6 Gs. Because of the wide speed range (top speed/stall speed) of the RVs, entry speeds for some maneuvers can also vary over a considerable range. For vertical maneuvers like loops, Immelman turns, and horizontal eights, the entry speeds have an inverse relationship to the Gs required to complete the maneuver. An entry speed near the low end of the speed range will require a higher G pull-up than for an entry speed near the top of the speed range. The entry speeds listed below are presented as general guidelines, as starting points for aerobatic testing. Differing airframe weights, engines, propellers, and pilot preferences will determine the ideal entry speeds.

- Loops, Horizontal Eights: 140-190 mph.
- Immelman Turns: 150-190 mph
- Aileron Rolls, Barrel rolls: 120-190 mph
- Snap Rolls: 80-110 mph
- Vertical Rolls: 180-190 mph
- Split-S: 100-110 mph

Note: All speeds are statute mph.

Please note that the recommended entry speeds for snap rolls are relatively low. One definition of a snap roll is that it is an accelerated stall with heavy yaw input. Because the RVs have good stall characteristics and good spin resistance, they also resist easy snap roll entry. Entered at speeds below 100 mph, snaps tend to be slow and wallowing. At above 100 mph, high G loads are required. For this reason, most RV pilots avoid snap rolls and concentrate on looping and rolling maneuvers more suited to the performance and handling qualities of these planes.

NOTE: For RV-14 speeds, please refer to the RV-14 V Speed Chart on the Van's Aircraft website. For RV-12/12iS speeds, please refer to the appropriate POH for the aircraft.

RECORDING FLIGHT TEST DATA

All pertinent data obtained during flight testing should be recorded in the aircraft log and/or flight manual. This should include data about limits reached, limit speeds, acceleration (G-loads) limits, etc. This is particularly important if testing limits were lower than suggested in this text. There will be a natural tendency for future pilots of this airplane to assume that it has been built and tested to the same standard as the prototype and other RVs. If an individual RV has not been flight tested to the design limits, a clear record of the test limits should be available. An "AEROBATICS PROHIBITED" placard should be prominently displayed on the instrument panel. Remember, though your RV may look like all others, it is really a one-of-a-kind airplane because you built it, and it is not identical to any other. Well recorded data will eliminate the need for assumptions on the part of future pilots. We can do without assumptions in this business.

A placard stating "This Aircraft is amateur built and does not comply with the federal safety regulations for standard aircraft" must be visible in the cockpit of your airworthy RV. As the pilot, it is well to reflect on this thought because you are a passenger also. The federal safety standard were developed for good reason. Just because amateur built airplanes are not required to comply with all safety regulations and design standards does not exempt them from suffering the possible consequences of non-compliance. Perhaps it is better for the builder to think of the intended wording as "has not been shown to comply" rather than "does not comply". Then, do everything possible to comply with the highest "self imposed" standards of workmanship and airmanship.

We will close by leaving you with a few quotes borrowed from the FAA Advisory Circular, AMATEUR-BUILT AIRCRAFT FLIGHT TESTING HANDBOOK.

"The laws of aerodynamics are unforgiving and the ground is hard." *Michael Collins.*

"The object of the game, gentlemen, is not to cheat death: the object is not to let him play." *Patrick Poteen, Sgt., U.S. Army.*

"Leave nothing to chance." *Tony Bingelis*

"Know your airplane, know it well, know its limitations, and above all--know your own limitations." *Bob Hoover*

"It is critically important that a test pilot never succumb to the temptation to do too much too soon, for that path leads but to the grave." *Richard Hallion.*

"Always leave yourself a way out." *Chuck Yeager.*

"One can get the proper insight into the practice of flying only by actual flying experiments." *Otto Lilienthal (1896)*

"Keep your brain a couple steps ahead of the airplane." *Neil Armstrong*

"A superior pilot uses superior judgment to avoid those situations which require the use of superior skill. *Old Aviation Proverb*

"Go from the known to the unknown--slowly!" *Chris Wheal, test pilot*.

Airspeed Calibration Run #1

Conditions & Data: 8,000' MSL 42 deg. F. 156 IAS

2675 RPM 20.5" Man. Pres. Sensenich 68x78 prop

E6B computations show that:

156 mph IAS at 8,000' and 42 deg. F. = 178 mph True Indicated AS. (ie: no calibration for system errors)

Run #1 from north to south:

Start 45° 41.0' Lat.

Finish 45° 31.0' Lat.

Distance = 10 NM time = 3 minute 55 seconds = 235 Seconds.

Speed (knots)=Dist/time=(10 NM/235 sec) X 3600 sec/hr = 153.2 NM/Hr.

Speed (mph) = speed (NM/Hr) x 1.15 = 176.2 mph

Run #2 from south to north:

Start 45° 31.0' Lat.

Finish 45° 41.0' Lat

Distance = 10 NM time = 3 minutes 52 seconds = 232 Seconds.

Speed (knots)=Dist/time=(10 NM/232 sec) X 3600 sec/hr = 155.2 NM/Hr.

Speed (mph) = speed (NM/Hr) x 1.15 = 178.5 mph

Average speed = (176.2 + 178.5) / 2 = 177.35 mph True airspeed.

(from above) True Indicated Airspeed = 178.5 = Approx. 1 percent calibration error.

Airspeed Calibration Run #2

Conditions and Data: 1000' MSL 76 deg. F. 171 IAS

2650 RPM 24" Man. Press.

E6B computations shown that:

171 mph at 1000' msl and 76 deg. F. = 177 mph True Indicated AS. (ie: no calibration for system errors)

Downwind leg: 3 miles in 55 seconds.

Speed (mph)=Dist/time=(3 miles/55 sec) X 3600 sec/hr = 196.4 mph.

Upwind leg: 3 miles in 75 seconds.

Speed (mph)=Dist/time=(3 miles/75 sec) X 3600 sec/hr = 144 mph.

Average speed = (196.4 + 144)/ 2 = 170.2 mph.

This sample shows a TIAS of 177 as opposed to a true calibrated speed of 170.2, or an airspeed indicator reading of about 4% high.

Erroneous calculation would be:

Average speed = (distance 1 + distance 2)/(time 1 + time 2) = (3 miles + 3 miles)/55 sec+75 sec) X 3600 sec/hr = 166 mph.

TEST RUNS USING LORAN OR GPS MAY BE USED TO CALIBRATE THE AIRSPEED SYSTEM

NOTES