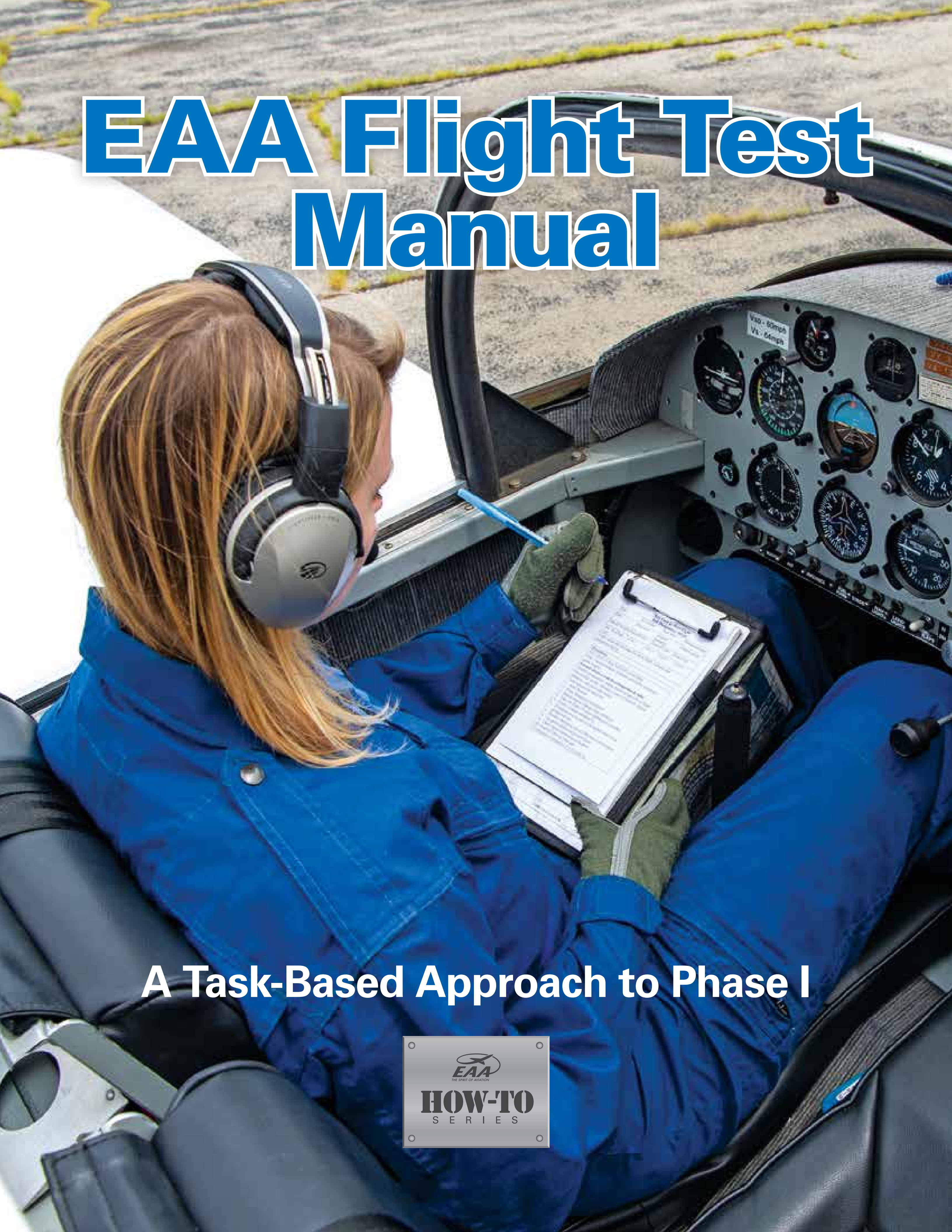
# EAA Flight Test Manual



## A Task-Based Approach to Phase I

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# EAA Flight Test Manual
# A Task-Based Approach to Phase I

Recognizing the best practices in the completion and flight testing of homebuilt aircraft

***Developed by:***
The Experimental Aircraft Association

***With Expert Writing and Review by:***
EAA Homebuilt Aircraft Council
EAA Board of Directors Safety Committee

Version 1.1 May 2021

# VERSION HISTORY

| VERSION | DATE | PAGES AFFECTED | DESCRIPTION OF CHANGE |
|---|---|---|---|
| 1.0 | October 2018 | N/A | Initial Release |
| 1.1 | May 2021 | 9 | Added note on risks of testing at aft CG |
| | | 10 | Corrected discrepancy in CG guidance |
| | | 26 | Amended preparation for VX/VY test |
| | | 36 | Corrected procedure for static directional stability test to match test card |

# Introduction

Orville and Wilbur Wright launched the homebuilt aircraft movement with their work that led to the first powered flight in 1903. The modern era of homebuilding began in 1952 when the government issued the regulation we know today as the 51 percent rule. In the last two decades, homebuilding has matured, becoming a vibrant industry dominated by kit aircraft. The number of amateur-built experimental aircraft on the FAA Registry has more than doubled in this time. Numbering more than 25,000, homebuilt aircraft represent approximately 20 percent of today's single-engine, piston-powered general aviation fleet.

Safety has always been the key to homebuilding's growth and success. The Experimental Aircraft Association has shepherded this effort since 1953, supporting it with workshops and safety programs that have created a nationwide corps of EAA technical counselors and flight advisors. However, there is always opportunity for improvement in the safety of amateur-built experimental aircraft. In 2011, the NTSB issued a report on safety trends in amateur-built aircraft, noting that the principal causes of accidents lie in pilot loss of control or engine failures and, interestingly, not from builder quality of construction issues. Further, FAA data shows the highest rate of accidents occurs in the first eight hours of Phase I flight testing and then decreases dramatically.  In answering the recommendations of the NTSB report, EAA has taken several initiatives to improve pilot preparedness for early flights in amateur-built aircraft. This *EAA Flight Test Manual* (*FTM*) is part of that effort and is aimed at maximizing pilots' preparedness for their individual aircraft programs.

The *EAA FTM* is a new curriculum designed by the EAA Homebuilt Aircraft Council (HAC) that encourages and expedites a safe program of inspection and flight testing for your amateur-built experimental aircraft. It focuses on the interplay between the experimental aircraft, the pilot, and the aircraft's performance, and combines essential information from magazine articles and FAA advisory circulars (especially AC 90-89B, *Amateur-Built Aircraft and Ultralight Flight Testing Handbook*) in a logical sequence of activities. These best practices will help you understand and verify the structural integrity, performance limitations, and flying qualities of your amateur-built experimental aircraft. Whether you built your aircraft or bought one in flying condition, this knowledge and firsthand experience is what you need for safe and satisfying flying.

The *EAA FTM* works in collaboration with the EAA Technical Counselor and Flight Advisor programs. Through a series of inspections and evaluations, these knowledgeable EAA volunteers offer guidance on your aircraft's design limitations, mechanical readiness, and basic flight characteristics, as well as your pilot proficiency and readiness to fly it. The *FTM* stresses the value of your compliance with its guidance, but using the manual is not mandatory. Whether you're a builder, second owner, or hired test pilot, you can begin using the *FTM* at any time. The key is to do it.

In September of 2014, the FAA and EAA completed AC 90-116, *Additional Pilot Program for Phase I Flight Test*, or APP (dated September 23, 2014). Today's reality of the ever-increasing complexity of modern kit aircraft is that Phase I flight testing assesses the capability of not only the aircraft but also the pilot. The APP was developed to address this and other issues, to improve safety by enhancing builder/owner skills, and to help mitigate the risks associated with Phase I flight testing of aircraft built from commercially available kits through the use of a qualified additional pilot and powerplant testing. The APP is an optional program that provides another tool for Phase I flight testing.

Your recent flight experience and your total flying time in the type of aircraft you are testing are critical safety considerations before starting flight testing. The FAA has recognized a need to devote resources to preventing accidents from occurring because of inadequate training when transitioning between aircraft types. It updated AC 90-109A, *Transition to Unfamiliar Aircraft*, in June 2015. Specifically, accidents resulting from loss of aircraft control or loss of situational awareness frequently result from pilot unpreparedness for challenges presented by the aircraft, or unfamiliarity with the test aircraft's flying qualities. You should consider transition training in an identical or similar aircraft as a fundamental part of your flight test preparation. Pilots transitioning to unfamiliar aircraft require specific training in the new aircraft's systems and operating characteristics to include normal, abnormal, and emergency procedures, and the EAA recommends a review of this AC as part of your test preparation.

There are three elements to the *FTM*: aircraft and test pilot preparation, flight testing, and developing your pilot's operating handbook (POH). Record-keeping is a critical part of each of these elements, beginning with your builder's log and continuing through your ongoing maintenance records and any modifications for the life of the aircraft. The goal of testing is to develop and compile the aircraft's performance and qualitative handling data for your POH. The Flight Testing section of the *FTM* covers the essential evaluations that a current, proficient pilot should be able to safely perform. There are 18 flight test cards that are provided in a sequence that is typical of a flight test program, plus one additional test card designed to help prepare the aircraft for its first flight. The cards are designated by relative risk level — high, medium, and low. For those interested in a more exhaustive flight test program, the References & Resources section of this manual will lead you to the necessary information.

Please send all corrections, comments, and suggestions for improvements to FTM@eaa.org.

# EAA Flight Test Manual Program Recognition

Participating in the EAA FTM program demonstrates your passion for quality homebuilding and safety. To recognize your dedication, sign this page at the end of your flight test period and EAA will send you an FTM decal for your airplane and a certificate for your wall. You will already have the most important reward for participating in the FTM program: the satisfaction and confidence that comes with knowledge gleaned from exploring your homebuilt's operating envelope. After completion of your flight test program, send (or scan and email) this page, with your signature, to:

**EAA FTM Program Recognition**
**P.O. Box 3086**
**Oshkosh, WI 54903-3085**

**email address: FTM@EAA.org**

### FTM Participation Checklist

| | | |
|---|---|---|
| Name | Builder Subsequent Owner (circle one) | |
| Type Aircraft | N-number | |
| Street | | |
| City | State | ZIP |

Having assembled and fabricated the major portion of the aircraft described here for my own education and/or recreation, I attest that I have:

1. Reviewed FAA Advisory Circular AC 90-116, *Additional Pilot Program for Phase I Flight Test*, to see if an additional pilot would be appropriate for my test flight program,

**AND**

2. Complied with the appropriate provisions of at least one of the following recommended test pilot proficiency programs:

   - FAA Advisory Circular AC 90-89B, *Amateur-Built Aircraft and Ultralight Flight Testing Handbook*, or
   - **FAA advisory circular AC 90-109A, *Transition to Unfamiliar Aircraft*, or**
   - A proficiency/transition program recommended by your type club or kit manufacturer,

**AND**

3. Completed the EAA Flight Test Manual program in its entirety to the best of my ability and that the aircraft is controllable throughout its flight envelope, has no characteristics that would affect its airworthiness, and is safe for operation.

Signed: ______________________________ Date: ______________________

# Table of Contents

# Section One - Aircraft Preparation

Whether you have just finished your homebuilt aircraft or bought one that is already flying, your safety depends on a series of inspections, checks, and tests that assess the aircraft's condition for safe operation. These assessments are covered in the Record-keeping, Fuel Flow & Unusable Fuel, and Weight & Balance sections of this manual and in completing the inspection checklist before the first flight.

Ideally, you'll begin record-keeping when you start building and lay out your cockpit controls and switches when you reach that stage of construction. If the airplane is already built, evaluate it using these guidelines and make changes as necessary. With this effort, you're establishing or confirming that the airplane is in a condition for safe flight.

Where appropriate, there are spaces for your signature and the date you completed the described inspection or test. This serves as a record that you have evaluated your aircraft using these guidelines and have found it in compliance.

## Record-keeping — Documenting Your Airplane's Life

Record-keeping is a necessary ally of aviation. Take your pilot logbook for example; it documents and verifies what you have learned, the tests you've passed, the experience you have accumulated, and the periodic evaluations of your abilities. When combined with your pilot certificate, a properly kept logbook is your key to the sky, unlocking the door to renting airplanes, getting insurance, and expanding your skills and knowledge with additional training.

Equally important to owners is record-keeping and its related paperwork for an individual aircraft. From the pilot's point of view, the acronym AROW identifies the documents that must be carried in the airplane at all times: airworthiness certificate, registration, operating limitations, and weight and balance information. An FAA representative or a designated airworthiness representative (DAR) will issue an original airworthiness certificate and associated operating limitations when the aircraft is ready for flight test. These are critical documents needed to fly within U.S. national airspace and are devilishly difficult to replace. If you are a second owner, be sure you get these documents as part of the transfer of ownership.

An aircraft's records are composed of the AROW documents and the aircraft logbooks that track maintenance, repair, and inspection of the airframe, engine, and propeller. As spelled out in FAR 91.417, the aircraft owner is responsible for keeping aircraft records, and as a homebuilder, you are the one who creates them.

Keeping good records does more than satisfy federal requirements. Well-kept records add value to your airplane because they present important information about your airplane's mechanical life to other people like insurance companies and prospective buyers. If you were buying a flying homebuilt, wouldn't you feel more secure after examining comprehensive and current logs? And should you buy the airplane, those logs become your responsibility.

*Building Logbooks & Equipment Lists*

A homebuilt's records start with the builder's log. What form it takes — print or computerized — really doesn't matter, but you should be able to print out the entries so you can endorse their veracity with your signature and present them to the inspector at the airplane's airworthiness exam.

How detailed your building entries are depends on you, but they should include the basics of all maintenance log entries:

- Describe the work done.
- Indicate the day the work was completed.
- Include the signature of the person who did the work.

When the pieces of the aircraft begin to come together to create something you can sit in, start keeping records in the airframe logbook. In most cases, when you purchase your powerplant it will come with a logbook. So will the propeller. With each entry in these logs, note the:

- Total time in service.
- Status of life-limited components.
- Time since the component's last overhaul.
- Current inspection status of the aircraft and its applicable components.

Record-keeping is easy if you do it every time you finish some task. It takes less time to make one entry than it does to try and remember what you've done and when. For example, how long would it take you to write in the prop logbook, "[Date] — Installed new propeller. Torqued bolts to [manufacturer's recommended value]. Time in service: 0. [Signed]."

An equipment list complements your logbooks. For every component and accessory you install on your airplane, record the item's name, serial/part number, where you bought it and when, when you installed it, what it weighs, and its location (arm) relative to the aircraft datum. Recording this information when you acquire each item is the easiest way to compile this list, which comes to play an important role in an airplane's weight and balance, and insurance.

Besides recording exactly what's on your airplane when you weigh it, the equipment list can save time should you replace or improve a listed item. If the replacement weighs the same, you don't need to reweigh the aircraft or compute the effect of the heavier or lighter item.

*Maintenance & Inspections*

As a homebuilder, you can repair, install, or replace most items on your airplane, and if you hold the repairman certificate for that aircraft, you can conduct its yearly condition inspection. Appropriately certificated facilities must perform the transponder and pitot-static inspections required for operation in today's airspace. Your homebuilt's operating limitations spell out any other details pertaining to your aircraft.

Every maintenance task and inspection is a step-by-step process and using a checklist is the best way to avoid missing any of them. Component manuals are a good place to start building maintenance task checklists. Appendix D of FAR Part 43 is the best place to start for the annual condition inspection checklist, and it is most likely referenced in your homebuilt's operating limitations. You can reference these maintenance checklists in your record entries. When it comes to the annual condition inspection, you can use a checklist to ensure that you don't miss anything, but the logbook entry must use the wording specified in the airplane's operating limitations.

*Repairs & Major Changes*

Most pilots have heard of FAA Form 337, the paperwork that standard-category aircraft owners must deal with for most repairs and changes made to their airplanes. Homebuilders don't have to worry about this. Instead, they make a maintenance record entry after completing a repair.

Making a major change to an amateur-built experimental aircraft involves a bit more work, however, but not much; the operating limitations spell out the requirements. FAR 21.93 defines a major change as anything that is not a minor change. A minor change is "one that has no appreciable effect on the weight, balance, structural strength, reliability, operational characteristics, or other characteristics affecting" airworthiness.

After incorporating a major change — and documenting it in your maintenance records — you must contact your FAA flight standards district office (FSDO), confirm the flight test area defined in your operating limitations, and possibly set up another test flight program like you did when you first flew the homebuilt. If the major change involves a different type or size of engine, or replacing the fixed-pitch prop with a constant-speed model, you'll have to fill out a new Form 8130-6 to update the aircraft file at the FAA Registry.

*Service Bulletins & Airworthiness Directives*

Many components used on homebuilt aircraft are designed and certificated for standard-category aircraft. By regulation, the manufacturers of these components must inform affected aircraft owners when addressing an unsafe situation — and its remedy — in a service bulletin. The FAA issues these safety mandates as an airworthiness directive (AD) that describes the problem and its solution in great detail.

Owners of standard-category aircraft must comply with ADs. Homebuilders are not legally bound unless the AD specifically says it applies to experimental amateur-built aircraft. On the other hand, the operating limitations for all amateur-built experimental aircraft require owners to keep their airplane in a condition for safe operation. As the owner, you decide what is safe. Be a good risk manager and consider how you would defend your decision to ignore a crankshaft AD, for example, after you had to make an emergency off-airport landing because it failed. Remember, as pilot and mechanic, you have a dual responsibility for ensuring that the "aircraft is in a condition for safe operation," and your signature testifies to that in your maintenance records.

Ultimately, record-keeping is about writing the story of your airplane's life, and each entry adds to the diary. The entry homebuilders most look forward to making comes at the end of the initial flight test period, when they write, "I certify that the prescribed flight test hours have been completed," meaning they can now carry passengers and fly their plane to the full extent prescribed in their operating limitations.

## Fuel Flow & Unusable Fuel Tests — Simple Tests Help Prevent Power Problems

Loss of power or engine failure during initial test flights in a newly minted, amateur-built aircraft is every builder's nightmare. Although fuel flow problems are a leading cause of incidents, this risk can be managed safely. Measuring the quantity of unusable fuel and running a fuel-flow test for each tank is simple, easy, and offers solid evidence of the fuel system's performance, giving you the confidence that no restrictions or problems exist in getting an adequate flow of fuel to your engine.

This test does not involve running the engine; it measures the fuel quantity that would flow to your engine under normal conditions. In a high-wing aircraft, this is the fuel that would flow through gravity; in a low-wing, it's the fuel that would most likely be delivered through the auxiliary fuel pump.

FAA AC 90-89B, *Amateur-Built Aircraft and Ultralight Flight Testing Handbook*, contains a detailed description of the fuel system testing recommendations for experimental amateur-built aircraft. These simple tests will help you to control your fuel risks, a key to safety. It will give you clear knowledge of any unusable fuel in your tanks and evaluate whether your system can and will supply adequate fuel to your engine in critical flight attitudes. In some cases where it is unsafe to ground-test your aircraft in the proper climb attitude AND you have built you fuel system EXACTLY to an already-proven design, you may perform this test at another attitude, at your discretion. Regardless, expect your DAR to ask you for your records of these tests.

*Some Preliminary Considerations*

The fuel line should be sized to adequately supply the required quantity of fuel. Your engine manufacturer will specify the required size. By using a 3/8-inch minimum tubing size, the additional concern of a vapor lock is reduced. It is also a good idea to use heat shields on the fuel lines as well as cooling shrouds around gascolators and mechanically driven fuel pumps. Do not use paper-type fuel filters that might collapse and block fuel flow if contaminated by water condensation in the fuel tanks.

Checking your fuel gauges is a final step in this risk management process. Fix the airplane in its level flight attitude, and, with the fuel tanks empty (except the unusable fuel quantity as per above), check to see that your fuel gauges read empty. Now add fuel to each tank at 2-gallon intervals and check the gauge readings. Record these readings. By comparing the recorded fuel quantities and their corresponding gauge readings, you will know their accuracies. If necessary, you can make up a simple cross-referencing chart for each gauge that will give you a fuel quantity corresponding to any gauge reading.

With the aircraft on its gear, repeat the process of adding 2-gallon units of fuel to each tank, measuring and marking the level on a measuring stick inserted into the tank filler opening. This will give you an accurate dipstick to carry with you in your accessory case and to use whenever you are unsure of the exact fuel quantity in any given tank. Running out of fuel on any flight is an entirely preventable and manageable risk.

Fuel flow and usable fuel test data have been derived and recorded in the POH.

Date:______________________________ Initials:__________________________________

*Fuel Flow for Atypical Engines*

Modern electronic ignition systems and fuel-injection systems have made some engines more efficient than the FAA's rather conservative recommendation of 0.55 pounds per horsepower-hour. If the fuel-flow test using this value proves adequate, don't worry. Only if the measured fuel-flow values are less than those targeted (or calculated) should we become concerned. However, use better fuel consumption figures only if they can be well justified. This is no place to cut corners.

Similarly, two-stroke engines are less efficient, and the fuel flow per horsepower per hour will be higher. Two-stroke owners can contact their engine manufacturer to get a flow value for maximum horsepower output to use in their calculations. Don't forget to apply the 150 percent safety factor for gravity-fed systems, or the 125 percent for pump-fed fuel systems, to your calculations.

*Weight and Balance Concerns for Flight Testing*

Because the CG location has such a significant effect on how an airplane flies — and flies safely — confirm the CG range for your own airplane. For your first flight, you want the CG located roughly one-quarter of its range back from the forward CG limit. If you are unsure of the forward CG limit for your aircraft, start with a CG location approximately 22.5 percent of the mean aerodynamic chord (MAC). Add and secure a ballast to achieve this location. Heavy books in a tote bag, properly secured by seat belts or straps, provide a good, safe ballast.

During the flight test program, proceed slowly when examining forward and aft CG loading conditions. Follow a preplanned program that expands the airplane's operating envelope. With a forward CG, conventional aircraft pitch control pressures will be higher and therefore larger pitch control inputs will be required. The aircraft becomes more stable as the CG moves forward, but excessively forward CGs can limit overall pitch control authority. With an aft location, the aircraft will become more sensitive to pitch control inputs, and more unstable. As the aft CG limit is exceeded and moves further aft, the aircraft will eventually depart controlled flight and stall in a nose-up attitude. Checking your aircraft's weight and CG location before every flight is critical to the safety of the flight and allows you to anticipate the handling qualities for the flight.

*Make Sure Controls Work Properly*

Verify the proper rigging and full travel of all flight controls. Verify the correct movement of trim tabs. Make sure that the autopilot can be manually overridden if installed. Double-check to be sure all jam nuts, safety wire, and cotton pins are properly installed on all flight controls and engine controls. Make sure engine controls have full travel and cushion — travel should be limited by the stops on the carburetor or fuel servo and prop governor and not be the controls themselves.

*Make Sure Instruments and Avionics Work Properly*

Test flight and engine instruments on the ground to the extent possible. Make sure all limits are programmed into electronic instruments and are marked on analog instruments. Have the transponder certified before flight if operating in airspace requiring a transponder. A pitot-static certification is recommended for all planes and required before IFR flight.

*Powered Operations Before Flight*

Do enough taxiing to test and seat in the brakes, but avoid excessive ground operations for proper engine break-in. Be careful not to overheat the engine with excessive ground running. Perform a full power run-up in a safe area to verify maximum static rpm and proper functioning of engine and prop. A constant-speed prop should attain full rpm. Verify that each magneto or electronic ignition system can sustain engine power and can be shut-off independently.

For more information on this subject, see the References & Resources section.

## Section Two - Flight Testing

FTM Flight Test — A sample flight test program for amateur-built experimental aircraft.

### Before You Begin

This sample flight test program is designed to guide homebuilders through a safe, thorough evaluation of their amateur-built experimental aircraft. In addition, these tests will derive performance numbers needed for safe operation and for inclusion in your POH. This sample provides generic examples because there is a great deal of variation among homebuilt aircraft and the pilots who fly them. Do not assume that the generic flight test cards are appropriate for your airplane, your flying environment, or your piloting skills.

Safety is the key element in any flight test program. Much has been written about safety as it relates to flight testing a homebuilt. Many key safety points are incorporated here, but many are not. For example, the FTM only scratches the surface of preparing the airplane and the builder for their first flight together — or whether the builder is the pilot who should be making the first flight. These decisions are best made by working with an EAA technical counselor and flight advisor face to face.

A thorough review of FAA AC 90-116, *Additional Pilot Program for Phase I Flight Test*, is recommended at this point. It describes, among other things, under what circumstances an amateur builder may include an additional qualified pilot in Phase I flight test operations.

### Key Points of Safety

**Prepare Yourself:** Meet with your EAA flight advisor to discuss the points to consider in making your airplane's first flight and conducting its initial test flights. In some circumstances, based on your pilot experience and currency, and what the airplane requires from its pilot, prudence suggests that someone with more relevant experience should do the flying. This is not an easy decision so think about it carefully and with a long-term view. Remember, you built your airplane not for a single flight, but for years of flying fun and adventure.

If you decide to fly the test program, make sure your pilot skills are current and well-exercised. A two-hour flight review after several years of not flying is not enough. Create a preparation plan with your EAA flight advisor. It should involve flying different types of airplanes, including the type you're building, if possible. To get the most from this experience, fly the tests you will perform on your airplane in another aircraft and record the necessary data on the test before flying the test in your aircraft. It is an especially good idea to fly the first flight profile in another aircraft before flying your first flight.

**Aviate:** In flight, never lose sight of your primary responsibility — to fly the aircraft. Just as in every other type of flying, navigating and communicating always follow aviating during the flight test.

**Do Your Homework:** Before starting your flight test program, research your airplane's instrumentation/avionics, performance, flight characteristics, limitations, and emergency procedures. Read everything you can find, and talk to your EAA flight advisor and other pilots who fly your make and model. If possible, become current in the type of aircraft you are building, or one similar to it.

**Use Ground Inspection Checklists:** Using a checklist to perform a thorough aircraft inspection before every ground or flight test is a key element of safety. It enables you to discover — and remedy — potential problems before flight, and it reduces the number of unknowns that can cause anxiety during test flights.

**Compute Weight and Balance:** Before the first flight, complete the initial weight and balance work described in Section One. Then compute the airplane's weight and balance before every test flight, recording the CG location and weight of the pilot, fuel, and any ballast. This step is essential when expanding the flight envelope at different CG loadings.

**Ballast Carefully:** If you add ballast to adjust the CG location for specific tests, put it where the structure will support the weight, and secure it so it will not move under any circumstances. When subjected to the sudden or unexpected forces of flight, bags of lead shot can "flow" and solid weights can distort bulkheads or shear attach bolts if the weight is not secured with some forethought. In most cases, you can achieve the desired CG location by securing the ballast in places designed to carry the load: passenger seats and the baggage area.

**Ground Fly Every Test:** Review the purpose and procedures of each test in advance. Fly the test while sitting in the cockpit on the ground. This will enable you to position kneeboards, pencils, watches, recording devices, and other equipment so they will not interfere with your ability to aviate. If you have access to a simulator, consider training to your test cards in the simulator as well. On test day, preflight the test card and fill in target airspeeds, altitudes, and any other useful reminders.

**Protective Equipment:** Given that head injury and exposure to fire are significant causes of serious and sometimes fatal injuries in general aviation it may be appropriate to wear a helmet and/or fire-resistant clothing during flight testing. However, if you plan to wear such equipment, make sure that you are comfortable wearing it in flight and can perform all flight test duties without restriction or interference. Confirm this by wearing and using your gear to perform a test card in another aircraft like yours.

**Parachute:** Before answering the question of whether you should wear a parachute, answer these questions: Can you open the canopy or door in flight, pushing it against the slipstream? Can you sit in the proper

position with the chute on? If your answers are yes, here's one more: Can you exit the airplane quickly and cleanly while wearing the parachute? Practicing this on the ground will provide the ultimate answer.

**Chase Plane:** In deciding whether to use a chase plane, consider what the observer in the chase plane would contribute to the flight. If it is worth the risk of collision, pick an experienced formation pilot and brief the flight conduct, communications plan, and individual responsibilities thoroughly.

**Self-Control:** When conducting a test, don't overload yourself. Set up each test with all the precision possible given the conditions. Record the data in manageable bits. If necessary, repeat the test runs to acquire the needed data. Abort the test run if your instinct or the results indicate something is wrong. Remember, the hair on the back of your neck is there for a reason. When it stands up, pay attention to it.

**Weather:** To minimize errors, most tests should be flown in calm conditions. The best time of day to conduct a test flight is usually early morning. If this is not possible, consider additional repeated test points to average more data. If the test card suggests three points, for example, consider collecting five or six points to improve averaging result.

**Instrumentation and Data Collection:** You are required to have basic flight and engine performance instrumentation in your aircraft. Most experimental amateur-built aircraft being built today have significantly more and better instrumentation than the minimum required, but some consider it ancillary or simply nice to have. Aircraft and engine instrumentation is critical to the safe operation of your aircraft. It must be installed, calibrated, and ground-tested prior to first flight.

When you're flying a test — fly the airplane. Analyze the results on the ground. The same goes for aerodynamic troubleshooting. A test program is a series of disciplined, methodical small steps.

**Electronic Flight Instrument Systems (EFIS):** If you have an EFIS installed, ensure that you are proficient in its operation. Familiarize yourself with the symbols, interface, and functionality of the system. Technology-related distractions in the cockpit can be serious safety hazards in flight.

Further, most electronic flight and engine instruments have impressive data collection capabilities. Consider using these features to your advantage during flight testing. There are several third-party services that will help you collect, visualize, and save all manner of flight and engine data.

**FTM Test Cards:** Every flight test program is a series of small steps rooted in safety that slowly and methodically expand the airplane's operating envelope. The sample FTM flight test cards are arranged in a logical sequence for safety, but you're not required to perform them in the order published. You might consider repeating some of the cards as desired, and some test cards (e.g., stall testing) require more than one flight to change CG and/or weight. As the pilot in command, you are responsible for the safe conduct of every flight in your test program, so consider every decision carefully and make small changes until you are comfortable with your aircraft's flight characteristics.

There are 18 test cards in this set, but this doesn't mean you will complete the test program in 18 flights.

You'll fly some of the tests at different gross weights and CG locations, as shown on the FTM flight test matrix.

Use extreme caution when testing your aircraft at its aft CG, and double-check your weight and balance calculations and loading. Ensure that you account for changes caused throughout the flight by fuel consumption. Methodically approach the aft CG limits of your aircraft incrementally over successive test flights, at your discretion. Never exceed any applicable manufacturer's limit or recommendation. Do not hesitate to consult a flight instructor, EAA flight advisor, or test pilot/additional pilot with regards to aft CG flight characteristics. While always important, free and clear control travel is especially critical, as is proper control deflection, when flying at aft CG.

When conducting tests at different weights and CG locations, two points take precedence:

- Never fly the airplane when its CG is forward or aft of the designer's recommended CG envelope.
- Never load the airplane so its gross weight exceeds the maximum limit recommended by its designer.

There are four parts to each test card. The pages that follow discuss each test procedure and how to derive the needed information from the test flight data. The individual kneeboard-size test cards present the tasks to be performed (and any necessary preflight calculations) and spaces in which to record the required data.

*The test cards have been annotated to indicate relative risk levels of the flight maneuvers associated with that test. The risk levels designated for each card are based on a typical aircraft. Unique characteristics of your design may dictate a different relative risk for some cards due to the nature of the maneuvers. You should make this assessment for your aircraft as part of your test flight planning. The test cards are each identified as high (H), medium (M), or low (L) risk.*

High-risk test maneuvers involve the highest likelihood of loss of control or other dangerous aircraft responses such as engine failure unexpectedly induced by a test maneuver. The first flight — as well as first exposures to the edges of the envelope (stall and/or $V_{NE}$, for example) — involves the kinds of tests that fall into the high-risk category. These tests should be performed only by highly proficient pilots after extensive preparation. Medium-risk tests are designated for those test points that still have some likelihood of leading to loss of control or other dangerous aircraft responses, but are performed after successful completion of the equivalent high-risk test point maneuvers. For example, repeating stall tests at progressively higher weights after successful initial stall testing is complete. Low-risk test points involve limited exposure to conditions or maneuvers — for example, cruise and endurance data collection — that could result in loss of control or other dangerous aircraft responses. Consider flying higher than the minimum test altitudes when possible.

# FTM Flight Test Matrix

| Test Card | Purpose | Recommended Test Weight & CG | | | | |
|---|---|---|---|---|---|---|
| | | Any | Light Forward | Heavy Forward | Light Aft | Heavy Aft |
| 0/M | Fuel Flow Test | ■ | | | | |
| 1/L | Ground Runs | | ■ | | | |
| 2/H | First Flight | | ■ | | | |
| 3/M | Landing Gear & Flaps | ■ | | | | |
| 4/L | Rough Pitot-Static Calibration | ■ | | | | |
| 5/M | Longitudinal Control | | | ■ | ■ | |
| 6/H | Wings-Level Stall & Stall Warning | | ■ | ■ | ■ | ■ |
| 7/L | Determine $V_Y$ & $V_X$ | | | ■ | | |
| 8/L | Glide | | | ■ | | |
| 9/L | Endurance & Range | | ■ | ■ | ■ | ■ |
| 10/L | Takeoff Performance | | ■ | ■ | ■ | ■ |
| 11/M | Landing Performance | | ■ | ■ | ■ | ■ |
| 12/H | Approach to Accelerated Stall | | ■ | ■ | ■ | ■ |
| 13/L | Trim Check | | | ■ | ■ | ■ |
| 14/M | Static Longitudinal Stability | | | ■ | ■ | ■ |
| 15/M | Static Directional Stability | | | ■ | ■ | ■ |
| 16/M | Static Lateral Stability/Spiral Stability | | | ■ | ■ | ■ |
| 17/M | Dynamic Stability | | | ■ | ■ | ■ |
| 18/M | Runaway Pitch Trim | | | ■ | ■ | ■ |

### Weight and CG Matrix Legend

*Any:* Valid test results do not depend on a specific weight or CG location.

*Light forward:* With pilot and 1.5 hours of fuel, the CG is one-fourth to one-third behind the designer's recommended forward CG limit.

*Heavy forward:* Full fuel and all seats forward of the CG are occupied or ballasted. Do not exceed maximum gross weight or designer's recommended forward CG limit.

*Light aft:* With pilot, 1.5 hours of fuel, and appropriate ballast secured in back seat or baggage area, the CG is 1/4 to 1/3 ahead of the designer's recommended aft CG limit.

*Heavy aft:* Full fuel, all seats occupied or ballasted, and maximum baggage that keeps the CG within the designer's recommended fore and aft limits and at or below maximum gross weight.

*Note: Aft CG is typically higher risk for flight test safety considerations.*

*Redline Speed Testing*

Knowing your airplane's performance throughout its speed range is a key to safe and efficient operation. Your flight tests will provide the data you need to quantify your airplane's best angle of climb and best rate of climb performance ($V_X$ and $V_Y$), maneuvering speed ($V_A$), and normal operating speed ($V_{NO}$). However, the 18 test cards intentionally do not include gathering flight test data for never exceed speed ($V_{NE}$) or for determining flutter margins. Maximum airspeed and flutter testing is not for the faint of heart or those not properly prepared, and it is best left to professionals. *There is an alternative to flying a homebuilt aircraft to its redline speed and seeing if it stays together*:

1. Build the airplane exactly as the kit/plans dictate using the recommended materials, components, and fabrication processes. Do not change or exceed the designer's recommended horsepower limits, weights, and CG limits.

2. Draw your airplane's redline speed 10 percent shy of the designer's recommended $V_{NE}$. For example, if the designer recommends 200, your redline speed would be 180. A number of kit companies recommend this approach, and many owners of amateur-built aircraft follow it.

3. Note the limits of this process on a placard, in the POH, and in the maintenance records, so anyone who flies the airplane will have this necessary information. Too often, airspeed indicators display the designer's limits, and we wonder how many of these speeds have been verified by testing. Some designers simply suggest that the limit be set and respected without further testing. The choice is yours.

If you decide to test the designer's recommended $V_{NE}$ limits, consult with the designer for his or her recommendations and consult a professional test pilot for the necessary procedures and required pilot skills. If you decide to conduct $V_{NE}$/flutter testing, hire a professional test pilot. We do not recommend any other option in this area.

*Maneuvering Speed*

Designers compute maneuvering speed as part of their stress analyses. It is not color-coded on the airspeed indicator. Maneuvering speed is related to the airplane's stall speed, so take your stall tests seriously. If your airplane stalls at the designer's speeds, then the recommended $V_A$ will work for your airplane. If your stall speeds and the designer's differ, you need to adjust the recommended maneuvering speed appropriately.

Just as aircraft weight affects the airplane's stall speed, it also affects $V_A$. Often, $V_A$ is given for the airplane's maximum gross weight. To find the maneuvering speed appropriate for lighter gross weights, reduce the max gross $V_A$ by 1 percent for every 2 percent decrease in the airplane's gross weight. For example, if the gross weight solo is 20 percent less than maximum gross, reduce your maximum gross maneuvering speed by 10 percent.

Make this computation part of your stall testing. After adjusting $V_A$ for any difference between the designer's stall speeds and what your airplane actually does, compute $V_A$ for each of the weights you fly during your wings-level stall tests and record them in the POH and on an instrument panel placard.

Always remember that the "safety valve" provided by maneuvering speed — reaching stall before overstressing the airframe — only applies to pulling pitch when in coordinated straight-and-level flight. If you add roll to the pitching movement by applying full aileron while pulling near-limit *g*'s at $V_A$, you will overstress the airplane because the wing moving up in a roll has a higher load factor than a wing in level attitude. Turbulence or pilot inputs in the roll axis will result in exceeding the load if the aircraft is at limit load at the time of the added input.

Your vital contribution to safe flight is determining your airplane's stall speeds. Knowing at what speed the airplane stalls at the full range of configurations and weights is key to avoiding overstressing your aircraft. Overstressing your aircraft is a very real possibility when conducting $V_{NE}$/flutter tests, which is why only a professional test pilot should undertake these tests. For a complete discussion of maneuvering speed and how pitch and roll act on an airplane, see "Maneuvering Diagram" by Ed Kolano in the February 2002 issue of *EAA Sport Aviation*.

## Test Card 0 — Fuel Flow Test

EAA safety data notes that fuel system issues are one of the most common problems discovered in Phase I flight testing. A 2014 EAA survey noted that 12 percent of aircraft in Phase I experienced fuel system problems, some of which are related to construction debris in the fuel system. You should check the fueling container for contaminants and discard or filter any fuel used during this test. The aircraft and container used for this test must also be properly grounded, as a lack of grounding can cause a fire. Refer to FAA AC 90-89B for additional information on testing fuel systems.

*Fuel System*

In servicing fuel systems, remember that fuel is flammable and that the danger of fire or explosion always exists. The following precautions should be taken:

- Aircraft being serviced or having the fuel system repaired must be properly grounded.
- Fueling and defueling operations should be accomplished outside with a fire extinguisher readily available.
- Spilled fuel must be neutralized or removed as quickly as possible.
- Open fuel lines must be capped.

*Fuel Cross-Feed, Firewall Shut-Off, and Tank Selector Valves*

Check for internal leakage by placing the appropriate valve in the off position, draining the fuel strainer bowl, and observing if fuel continues to flow into it. Check all of the valves located downstream of the boost pump(s) with the pump(s) operating. Do not operate the pump(s) longer than necessary. External leakage from these units can result in a severe fire hazard, especially if the unit is located under the cabin floor or within a similarly confined area.

Check the operation of each handle or control to see that it indicates the actual position of the selector valve to the placard location. Movement of the selector handle should be smooth and free of binding. Ensure that stops and detents have positive action and smooth operational feel.

Check each strainer and filter element for contamination. Determine and correct the source of any contaminants found. Examine fuel strainer bowls to see that they are properly installed according to the direction of the fuel flow. Check the operation of all drain devices to see that they operate properly and have positive shutoff action.

## Test Card 1 — Engine Run and Taxi Tests

Ensuring the proper operation of your homebuilt's engine, evaluating its slow-speed taxi characteristics, and wearing in your brakes are the primary goals of engine runs and taxi tests.

Expect the unexpected on your first engine start. Surprises can range from backfires to stuck throttle settings. Take proper precautions: use wheel chocks and tie down the airplane. Have at least one observer with a fire extinguisher.

Leave the door or canopy open, if possible, and brief the observer on the signal that will alert you to pull the mixture to cutoff, turn the fuel valve off, shut down all electrical power, and evacuate the cockpit immediately thereafter. You should have confirmed that your fuel selector valve has an effective off position during your fuel flow tests.

To build confidence in your powerplant before the first flight, you will probably need several engine tests to collect the necessary startup and operating temperatures and pressures. Methodically recording the test-card data builds a baseline of normal readings and will help identify problems. Modify the test card as appropriate to your engine.

Many pilots remove the cowling for this test because it saves time when looking for leaks (and putting out an engine fire). But remember, heat is an engine's enemy. Keep a close eye on all temperatures, and keep them in the green. Stop the test if temperatures climb out of this range, and investigate the cause. After higher power runs, let the engine gradually cool by running it at lower power settings before shutting it down.

Use a different shutdown method for successive ground runs. Switching the ignition switch off for a second verifies its operation and that the magnetos are properly grounded. Turning off the fuel selector valve reveals how long it takes the engine to quit at idle power. This time will be shorter at higher power settings.

*New and Overhauled Engines*

A new or recently overhauled aircraft engine and a homebuilt about to make its first flight are not a good combination. To properly seat the piston rings, you need to break in the engine by using high power settings for the manufacturer-recommended time. Running the engine at the top of the tachometer's green arc is not conducive for safe taxi or brake tests or first flights because you need to throttle back to achieve the proper speed.

If you must work with an engine that needs breaking in, make sure you run the appropriate manufac-

turer-recommended test-cell regimen for at least an hour to make sure all of the parts are working together properly and at the correct temperatures. Without this, your airplane is the test cell.

On all runs of a new or recently overhauled engine, make sure you keep all temperature limits in the green. On the first flight, plan on at least 30 minutes at 75 percent power and a mixture rich of peak. During the break-in, make one-hour flights at cruise power settings with shorter periods of high power settings. Don't make touch-and-goes.

If you have a constant-speed prop, don't cycle it heavily. This lowers the engine's oil pressure, which has the same effect on your engine as when a person stands up too quickly. Instead of making the engine dizzy, it increases wear. Cycling the prop for a 100-rpm drop will let you know all is well.

As an engine breaks in, the idle rpm often increases because of decreased friction. Adjust the idle to the manufacturer-recommended value using the appropriate adjustment. Ultimately, your best operating guidance is the manufacturer or overhauler's recommendations.

*Taxi and Brake Tests*

For maximum brake effectiveness, you need to follow the manufacturer's wear-in procedure. You can assess your airplane's ground handling at the same time. Before taxiing, check the brakes for normal pressure by depressing the brake pedals.

In a no-wind situation and at a taxi speed no faster than a person jogs, note how the airplane tracks a straight line with your feet off the rudder pedals. The wheels should roll smoothly; if the airplane wants to wander to one side or the other, or the tires show uneven scuffing, you'll need to experiment with different toe-in and toe-out settings, which align the wheels parallel to the airplane's direction of travel.

Then make left and right turns (with and without brakes, as appropriate to your airplane). If the airplane turns more sharply than the control input suggests, you'll need to discover the cause of its over-steering tendency. If the airplane turns shallower than the control input suggests, look for the cause of under-steering.

If the airplane tracks and turns properly at slow speeds, it will probably do the same at higher speeds. During all of your taxi tests and brake wear-in, monitor engine temperatures closely and keep them in the green.

Prolonged running at low power settings is detrimental to the break-in process. Perform these tests with that in mind, and do not dally.

## Test Card 2 — First Flight

Controlling the airplane and a pilot's natural anxiety are complementary first flight goals. Preparation is the key to managing the risks associated with the first flight. Successful completion of inspection checklists, engine runs, and taxi tests verifies that the airplane is ready for the first flight. Besides revealing problems to remedy these inspections and tests, they turn unknowns into first-hand experience.

An EAA flight advisor should identify the airplane's flight characteristics and evaluate the pilot's ability to safely control them. In some cases, the safest course is to have a pilot who's more familiar with the airplane type make the first flight. In many cases, the flight advisor and pilot can devise a preparation plan that ensures the pilot is current and capable and intimately knows the test airplane's performance numbers, limitations, flight characteristics, and emergency procedures.

The first flight is a methodical, disciplined step in the test program. It is not a spectator event. Crowds may, by invitation or word of mouth, gather for the flight, but the pilot cannot allow their presence to influence his or her decision to fly. It is best if only a few knowledgeable individuals are present and that each person knows his or her role. This is particularly important in the event of an emergency. The hallmark of a wise test pilot is refusing to fly an airplane that is not ready for flight.

We are confronted with many choices when planning and executing an aircraft flight test program. Experience also tells us there is often not a single, best way to perform flight tests. Judgment calls must be made on a number of choices, such as whether or not to include high-speed taxi and runway flights prior to the first up-and-away flight.

*High Speed Taxi Tests*

As you plan your test program, you should consider the benefits and risks of conducting high-speed taxi tests. There's a lot to consider in this decision. A high-speed taxi and runway flight is not a maneuver we are trained to do in normal flying. Stabilizing at speeds at or near flying speed requires reducing power so as to not fly away. The maneuver uses significant runway, and we are deliberately extending the time spent in a regime that has limited margin for error if directional control issues arise. Executing a stop from these maneuvers can also potentially overheat the wheels and brakes.

On the other hand, if the risks are adequately mitigated, the high-speed taxi and runway flight can help discover handling qualities issues while still being able to stop straight ahead. If you have unexpected, significant out-of-trim conditions, or unexpected flight control responsiveness, having planned ahead of time to stay on or just above the runway may result in less total risk than fighting the aircraft around the pattern and trying to land. Also, if built up in an incremental fashion, high-speed taxi and runway flights can give the pilot a better feel for the aircraft before the first full approach and landing. Additionally, if you are flying a common design, you will be able to cross-check your takeoff and stopping distance performance against the published data and potentially discover discrepancies that point to aircraft problems before the real first flight. If you're taking a lot more distance to rotate, is it a power issue, an elevator authority or rigging issue, or something else? Find out and fix it before you make that first full up-and-away flight.

If you elect to conduct high-speed taxi tests prior to the first flight, a simple exercise that is a must for your planning is to calculate expected takeoff and landing distances and derive a minimum acceptable runway length for the tests. Using available performance charts (or engineering predictions if yours is a new design), calculate both the distance to takeoff and the distance for a normal landing roll. You must also account for the time and distance you will spend at the target airspeed (at or near the takeoff speed) if you perform high-speed taxi tests and runway flights. Calculate the distance used at the target condition by converting the speed to feet per second. (Note: One knot is equal to 1.69 feet per second). If your target speed for a test run is 60 knots, the aircraft will be using up just more than 100 feet of runway for every second you hold the target speed. You should plan on 5-10 seconds once you get to the target speed, as you'll be surprised how quickly the seconds go by. Adding up takeoff roll, distance at the target speed, and the expected stopping distance, you can see how much runway you will be using for the various target speeds you plan to fly. Add a significant margin for safety to this number, and determine if the airport you plan to fly from is adequate for early flight tests. The calculations for many typical homebuilt aircraft could yield the need for a minimum runway length of 4,500 feet for testing, with 6,000 feet preferred.

Think of the high-speed taxi or runway flight as a four-part maneuver: initial acceleration to target speed, power reduction to hold the target speed, assessment of aircraft response, and abort. If you don't take at least a few seconds at the target speed, you will not be able to observe the aircraft's performance and responsiveness, which was the whole purpose for the test point to begin with. If you elect to accept the risk of this maneuver, then you need to be able to get the data that justifies it.

On any early test flight, make sure you have calm winds, smooth air, minimum practical weight, and adequate runway. If you choose to perform the high-speed taxis and runway flights, gain some experience with the maneuver in another aircraft in which you are already very comfortable. Even better, do them in more than one type you have experience in so you can see variances. For the high-speed taxi and runway flight test technique, choose target speeds that build up gradually to flying speed, for example, in 5-knot increments. At each target speed, make small control inputs in each axis and observe the response. Allow adequate time for the wheels and brakes to cool before another test, and take off the wheelpants if the aircraft has them. If you can perform your tests at a runway with distance remaining markers, you can also get distance performance data as you perform the test points. Complete the sequence with a brief liftoff to a few feet above the runway to check trim and control response prior to the first up-and-away flight.

The type of aircraft is a final consideration. If you are flying a common design and can get time in another like yours prior to your own first flight, you may have less to gain from the high-speed taxi and runway flights than someone who has a unique or modified design. Whatever path you choose, plan thoroughly, practice your test sequence in another aircraft, and build up slowly in testing the aircraft's full envelope capability.

*Using a Chase Aircraft*

Putting two aircraft in the sky together complicates the operation, so you must think very carefully about why and how you might pursue this. For some situations, using a chase plane can be a benefit, but it has to be for very specific objectives with careful planning.

The use of a chase plane in flight testing is a very common practice in the military as well as in certain aspects of commercial aircraft programs. The benefits are numerous, but so are the risks of added complexity. Fundamentally, a chase aircraft can inform the test aircraft's pilot of unnoticed hazardous situations, such as fluid leaks on the aircraft exterior or unexpected behavior of flight controls or landing gear during operation. The chase plane can also help collect test data, confirm that basic airspeed and altitude readouts in the test aircraft are correct, make calls to air traffic control, perform photo documentation, and, in emergencies, provide critical advice to help successfully recover the aircraft. Done in an effective manner by proficient pilots, the chase plane can dramatically reduce the test aircraft pilot's workload. However, done incorrectly, it will without question dramatically overburden the operation and create much greater risk for the test aircraft's pilot. Without considerable experience and proficiency in formation flying, a chase aircraft has no place in the flight test program.

A flight test with a chase aircraft is also considerably different than other formation flying. In particular, the test aircraft's pilot can't afford to "manage" the wingman actively (directing wingman maneuvers, managing formation radio frequency changes, and monitoring the wingman's position), given his or her focus has to be on the test aircraft. In general, this means the test aircraft's pilot performs the flight test almost as if the chase aircraft isn't there, and the chase pilot has to be thoroughly familiar with the test sequence and know when to (and when not to) speak up on the radio. This requires significant preflight rehearsal and coordination.

When planning to use a chase aircraft, there are a number of considerations. First is the chase aircraft type. Ideally, the aircraft will have similar or slightly better performance characteristics than the test aircraft. It also should be a multi-place aircraft that enables any necessary photography. The chase pilot should never be performing photography, instead striving for 100 percent eyes-on monitoring of the test aircraft from the pre-briefed position for each test point. There is a tragic example of two single-seat U.S. Air Force A-7 aircraft colliding when the wingman attempted to film a rejoin with his leader while looking through the camera viewfinder, unaware that the lens gave the perception that the other aircraft was much farther away than it really was. The role of photography belongs with a second pilot or passenger in the chase aircraft.

Beyond the choice of the chase aircraft type and the crew that flies it, the most important considerations are the objectives to be met. What specific role will the chase have for each of the test points on the flight test card? How will the test aircraft flight profile be sequenced, and how will the chase aircraft plan its flight so as to be in the proper position continuously? How important to the flight test purpose is the chase aircraft? Even in a military flight test program, there are very few occasions where a planned test flight will be canceled if the chase aircraft aborts due to a maintenance problem. Those test points where the chase aircraft is mandatory are carefully scrutinized and planned, and much of the test program can be performed without the chase. The bottom line is a chase is most often nice to have, occasionally a requirement for data collection/video and photography, and on a rare occasion a real lifesaver in certain types of emergencies.

If answers to the above questions in your situation lead you to opt for a chase plane for your flight test program, consider some of the following guidelines for flight planning. Use an airport with a long runway and low traffic, and have the chase orbit above the field prior to the test aircraft's departure. As the test aircraft performs its initial climb-out, the chase maneuvers to a position off the test aircraft's wing as briefed.

From there, the test pilot simply calls out where he or she is in the sequence of the test points so the chase can follow along, collect visual and/or photo documentation, and advise the test pilot of any necessary information during the flight. Always keep in mind that having a wingman in the air with you in another aircraft is something you should only pursue with explicit objectives in mind and with highly proficient pilots who are experienced in that kind of flight operation.

*First Flight Procedures*

Before first flight, coordinate your activities as appropriate with the airport, tower, and emergency services. Recruit and brief your ground observer, who should have a copy of the test card and a radio. This gives you a second set of eyes and a free hand to record the data you send via radio. You can also assign these duties to the chase pilot per the above if you elect to use one. If installed, set your electronic instrumentation to collect data automatically — if it can be done without interfering with your primary objectives below.

Procedures for first flight are simple and are a basic check of controllability and engine reliability. Use a well-thought-out checklist to ensure you will not miss anything. After verifying that the engine is performing correctly, liftoff is the first test of the wings. At this point, your "pilot senses" should be immediately attuned to the airplane's every action, and you must provide the proper correction without overcorrecting.

If appropriate for your airplane, make the first takeoff with the flaps up to reduce variables. If the landing gear retracts, do not jeopardize a safe first flight by testing this system — leave the gear down. Your goal is a safe, short, and controlled first flight that concludes with a safe landing — and a thorough post-flight inspection to detect any problems.

After liftoff, note the indicated airspeed and climb straight ahead to an altitude that gives you room to recover from an unexpected attitude that could result from rolling into a turn with heavy or twitchy ailerons. To ensure adequate fuel flow, your climb attitude should not be greater than the angle you tested during your ground test. *Remember, fuel system malfunction is a leading cause of first-flight mishaps.* Climbing in a loose box pattern that remains over the runway pattern is a good option to enable easiest recovery from any emergency.

When leveling off, set the power to maintain a speed well above stall speed but slower than cruise speed — at least 1.5 times the predicted stall speed works well. For high-performance airplanes, 150 knots, or the extended landing gear speed ($V_{LE}$), are reasonable first-flight limits that allow you to evaluate controllability and reduce the threat of flutter. If you elected to use a chase, compare your airspeed and altitude readings with that aircraft.

Trim the aircraft for straight-and-level flight and relax your control inputs for the initial controllability test. Note how well (or not) the aircraft maintains a trimmed condition and where the control surfaces and trim tabs must be for this middle-of-the-envelope stable point. When you are assured that flying the airplane won't require your total concentration, monitor the engine instruments.

Hot oil and cylinder-head temperatures are common first-flight problems, but they are not reasons to execute a hurried landing. The heat may be the result of taxi and climb, and the oil or cylinder heads will likely cool sufficiently during a controlled descent to a good approach and landing. If you must land before attempting slow flight, fly the approach at a speed a bit faster than your liftoff speed and remember that the airplane will float before touching down because it is carrying this extra speed. This is one of the reasons you should choose an airport with lots of runway for initial testing.

If engine readings are good, verify the trueness of the wing by noting the aileron deflection required for straight-and-level flight. If both ailerons are trailing edge up, this may indicate excessive play or looseness in the pushrods or cables. Make a note of this condition or radio it to your ground crew for later reference.

After checking the ailerons, make a gentle rudder input that yaws the nose 5 degrees to the left, and then the right, and note what percentage of pedal travel this input requires. This input should not induce an excessive pitch change, and the airplane should center itself after removing the rudder input. If the airplane does exhibit excessive pitch changes, avoid rudder inputs during landing.

Testing stall speed on the first flight is neither necessary nor advisable, but experiencing the airplane's characteristics at the approach speed is desirable before your first landing. At a safe altitude, make a controlled deceleration to the target touchdown speed, or to the limit of your comfort. Your liftoff airspeed is a good target. You should do this from an initial stabilized power-on approach condition and then simulate the power/speed reduction that you anticipate using to make the first landing. Go no slower than the onset of airframe buffet. Note the slowest speed attained and increase it by 40 percent to determine your target approach speed. Then use this speed to make a practice landing at altitude, recording the power settings and descent rate. Repeat these settings to make a safe landing.

If you don't have a carbon monoxide monitor installed in your aircraft, consider carrying a portable unit on your first flight to verify no carbon monoxide problems exist. The monitor should be able to read less than 50 parts per million (ppm).

Until you're comfortable that you've verified basic aircraft controllability and engine reliability, repeat this test profile in whole or in part. For a thorough discussion of the first flight, read the documents noted in the References & Resources section of this FTM manual.

### Test Card 3 — Gear and Flap Operation

If the landing gear retracts, the mechanism that makes this happen is usually the airplane's most complicated system. Anything on the airplane that moves may affect control of the airplane if it does not move as intended. Considering this, you need a healthy altitude buffer — 5,000 feet AGL is good — when testing retractable landing gear and the flaps.

Before testing the landing gear in flight, you should already have tested their operation on the ground (including the gear's emergency extension) and be sure they operate flawlessly. Your checklist is important at this point and in large part should be based on these ground tests. Whether electrical, hydraulic, or manual, you should fully understand how each component works and in what order. However, these tests didn't include the effects of the slipstream.

For this test you fly the first-flight profile. Make a no-flap takeoff (if applicable to your airplane), leave the gear down, and climb to a safe altitude, for example 2,000 feet AGL, then make a gentle 180-degree turn to stay over the airport. Do not perform the tests until you've leveled off at a safe altitude and configured the airplane for the appropriate speed — no faster than the recommended gear operation speed ($V_{LO}$).

Test gear retraction first; this gives you sufficient fuel to troubleshoot any problems that arise. A ground observer (or well-briefed chase pilot) familiar with the appearance of fully extended gear can back up the gear position indicator. Cycle the gear up and down several times to ensure that the air load does not hinder its operation. If the gear does not retract, do not make a second attempt.

*Flap Tests*

Flap operation often causes a pitch change, and, from your research, you should know how your airplane should react. At the proper flap operation speed ($V_{FE}$), or at least 1.5 times the estimated flaps-up stall speed ($V_S$), investigate this reaction in increments, one notch of flaps at a time. With electric flaps, ensure you can quickly and easily locate and pull the circuit breaker should a problem develop.

On the ground, you will have already verified the flaps' symmetric operation, but in flight you should anticipate the possibility of asymmetry. Should one flap move and the other stay where it is, the aircraft will immediately start rolling when the flaps are moved. If this happens, try to ascertain its cause, and do not immediately attempt to further move the flaps unless it's necessary for control of the aircraft. Otherwise, after verifying that actuation of the flaps will not exacerbate the problem, return the flap setting to the last point of symmetry.

If you decide that landing with an asymmetric flap extension is your safest (or only) course of action, fly a simulated approach and landing at an altitude that allows you to recover from an unusual attitude. During this simulated approach, slow to a reasonable landing speed and watch for any aileron or rudder control limit. Do not slow to stall speed. During your landing approach, do not go below the asymmetric flap landing speed.

Once you've verified the normal operation of the flaps, fly straight and level in slow flight at each increment of flaps, from the takeoff setting to full extension. To determine your approach reference speed for each flap setting, pull the power to idle, decelerate in 5-knot or 5-mph increments until the onset of the stall buffet or your comfort level of your ability to control the airplane. Then add 40 percent to the minimum speed attained. Climb back to a safe altitude and simulate an approach and landing to determine the power settings that give the desired performance in the traffic pattern and on final approach.

*Note that stall testing is Test Card 6 in the sequence, so the objective here is not to perform a full stall investigation. However, you should fully familiarize yourself with the approach to stall flight test techniques and be prepared to discontinue below any speed where abnormal aircraft response or unexpected response to flight control inputs occur.*

## Test Card 4 — Rough Pitot-Static Check

Before progressing much further into the flight test program it is important to know that the aircraft altitude and airspeed indicating systems are reasonably calibrated. To calibrate your airplane's airspeed indicator and pitot-static system, fly a square pattern and record each leg's groundspeed with GPS. If possible, perform this test on a no-wind day, or when the winds aloft are light and constant. This test is not completely accurate because it assumes that the averaged groundspeeds will be close to the airplane's true airspeed, but the results will be accurate enough to determine if the airspeed indicator, and the pitot-static system that operates it, is reasonable and usable. The ball should be centered for these tests to eliminate asymmetric static pressure, especially on aircraft with only one static port.

During preflight, compute the desired test speeds and fill them in on the test card.

For the best results, fly each leg of the square on a cardinal compass heading for about one minute at the same altitude with as little plus or minus variation as possible. Select the target indicated airspeeds with the low end at 1.3 stall speed ($V_S$) and the high end at maximum straight-and-level speed ($V_{NE}$) minus 10 knots or mph (or maximum speed attained so far, if lower). If the difference between high and low speeds is greater than 50 knots, add another point in between.

Maintaining the same indicated airspeed — without changing the power setting — is another indication of level flight. Do not record the GPS groundspeed figure until you've been in stabilized straight-and-level flight for at least 15 seconds. This is most easily attained in smooth air with the airplane in perfect trim.

You also need to record the pressure altitude and outside air temperature at your safe test altitude. Record the pressure altitude, if possible. If you don't have an outside air temperature gauge, use the temperature from the winds aloft forecast to get the best estimate.

Flap position can affect pitot-static accuracy because it changes the airflow around the airplane. To evaluate this, repeat the test at different configurations given on the test card. If the calculated error exceeds 10 percent of the test airspeed, and the system has been determined to be free of leaks, consider changing the position of the static port and/or the pitot tube.

If you elected to use a chase aircraft, it can be very helpful in assisting with both the airspeed and altitude checks. In particular, if the chase aircraft is a production aircraft from a major manufacturer, it will most likely have its own pitot-static system position errors included in the POH performance data for both airspeed and altitude. Furthermore, any chase aircraft should, at a minimum, have instrument errors available from the last pitot-static transponder check performed by an avionics technician. The instrument errors are specific to the altimeter and airspeed indicator installed in your aircraft, while the position errors in the POH are specific to the errors of that type aircraft that are induced by the position of the pitot and static ports in the airflow field. By stabilizing in close formation, unaccelerated, level flight, the test aircraft can record airspeeds and altitudes synchronized with the chase aircraft readings. Later, the chase data can be corrected for both the instrument errors and the position errors provided in the POH to get corrected readings for post-flight comparison to the test aircraft. The differences between the chase corrected readings and the test aircraft's in-flight readings

represent the total errors of the test aircraft system. Similarly, that total error can be separated into position error and instrument error for the test aircraft, if the instrument errors have been recorded.

*Number Crunching*

Average the four GPS groundspeeds for each test by adding the numbers and dividing by four. This average will approximate the airplane's true airspeed. For the same configuration, use an E-6B flight computer and the indicated airspeed, outside air temperature, and pressure altitude to calculate the true airspeed. Compare this result to the GPS average.

The system error is the difference between the two numbers, and it tells whether your airspeed indicator is reading higher or lower. You can refine the error by converting the difference from true to indicated airspeed with a flight computer.

You can find a similar, but mathematically more perfect test by visiting www.NTPS.edu, entering "Using GPS to Determine Pitot-Static Errors" into the search bar, and downloading the documents titled "GPS PEC Method" and "GPS PEC Spreadsheets." The test, written by Gregory V. Lewis of the National Test Pilot School, includes a procedure document and data compilation spreadsheet.

## Test Card 5 — Longitudinal Control

Any airplane must have sufficient pitch control throughout the operating envelope to fly safely. Simultaneously making power and flap changes often makes the greatest demands on this authority. This test ascertains the elevator's control authority when operating the flaps under specific conditions without excessive control force requirements. If the aircraft does not have flaps, conduct the test with variances in power settings to examine longitudinal control effects.

At a safe altitude — at least 5,000 feet AGL — fly this test series twice, first at a light-forward CG location and then with a light-aft CG. To prevent an unexpected pitch-up when simultaneously adding power and retracting the flaps, fly the forward CG test first.

During the test, you will extend and retract the flaps to and from different settings at different speeds. Start with the smallest increment of flaps at the slowest speed and work up to full flaps at the fastest speed ($V_{FE}$). Record your data points and comments, such as how heavy the pitch force was.

If your flaps are electric, make sure the motor can repeatedly extend and retract the flaps without overheating. If necessary, give it a chance to cool before performing the test configuration.

If your tests reveal that your airplane has marginal pitch control at full flaps, consider reducing the maximum flap extension, reducing the maximum flap extension speed, or investigating the adequacy of the horizontal tail.

## Test Card 6 — Wings-Level Stalls

Among the most challenging and certainly among the most high-risk testing that is done in a new aircraft is exploring flight near the edge of the envelope. Understanding the unique cues of your aircraft — how it talks to you — is critical to ensuring an appropriate reaction should you unintentionally get near stall. One additional reality with amateur-built aircraft is that individual builder variations (especially things like wing twist and contour) tend to show up more dramatically in slow speed characteristics than in middle-of-the-envelope flight. The sum of these considerations makes stall testing among the most important things you will do in the Phase I flight testing of your amateur-built aircraft.

Stall testing seeks to verify that the aircraft conforms to the expected responses for the particular design in this flight regime. You first need to have a thorough description of how the aircraft is expected to behave near, at, and after stall (i.e., from the designer). This provides detailed reference points to compare against your own flight test results. So what is an adequate description? The 1978 C-172N POH says this about stalls: "Characteristics are conventional and aural warning is provided by a stall warning horn which sounds between 5 and 10 knots above the stall in all configurations." This might be good enough for users after testing is complete but does not include the detail needed to prepare for your flight test.

What defines "conventional?" The Cessna 172 elevator control gets heavier as the aircraft slows down, the airframe begins to buffet slightly, the horn comes on, and then there is a mild nose drop (*g* break) followed by immediate recovery when the pilot relaxes the back-pressure and adds power. Total altitude loss is just a couple hundred feet. This description of conventional adds the kind of details a test pilot needs to be watching for in flight. The more complete the description, the better the ability to test for the expected result. The description needs to cover all configurations, all types of entry, stall warning types, expected stall speeds and margin before stall, what cue defines a stall, the best means to break the stall, and altitude loss in recovery. A thorough description comes from the manufacturer, in the case of a kit, or through lots of research and analysis for a unique design.

Make sure the weight and balance for the test is correct and determine where to load the aircraft for each test. Typically, it is safest to begin at light weights and forward CG, moving progressively to aft CG, then to heavier weights throughout the CG envelope. Aft CG testing of stalls is a high-risk area, and the importance of accurately managing weight and balance can't be overemphasized. Aft CG limits are often established for controllability concerns.

Before beginning stall testing, you should determine the accuracy of the pitot-static system. This requires satisfactory completion of the calculations from Test Card 4. Next, you need to make sure you're ready as the pilot. It is most important to be prepared for the potential of a delayed stall recovery or spin entry. Make sure you're current and comfortable in your ability to recover from unusual attitudes and spins by training in another suitable aircraft. Practicing stalls in the same or similar type aircraft will help you recognize your aircraft's unique characteristics. If you have any doubt about your proficiency, seek the help of a professional test pilot. If the design has never been spin tested, seriously consider hiring a pro. Read the spin testing section of AC 90-89B, *Amateur-Built Aircraft & Ultralight Testing Handbook*.

No matter who flies the tests, when they are complete you will know how much warning the airplane gives in the form of a buffet, the indicated airspeed at which the aircraft stalls, and how it behaves after it stalls. Make sure the engine's idle speed is properly set; faster idle speeds result in higher nose-up attitudes and lower indicated stall speeds.

When ready to fly, your testing should go from least risk to greatest and would therefore begin with clean configuration, wings-level stalls at a forward CG. Only after these are successful should you progress to gear and flap configurations, and, finally, to maneuvering (departure, turning, and accelerated) stalls. For each of these, the general test technique is similar. Begin by stabilizing in level flight at 15-20 knots above the predicted stall speed, at a safe altitude. Eight thousand feet AGL is good for most homebuilt aircraft, but it depends on the type. When stable, make a control input in each axis: roll, pitch, and yaw. The inputs should be just enough to generate about 3-5 degrees of aircraft response. Then, move the controls back to neutral (usually a one to two second input pulse). Watch for the aircraft response. In roll, is there any accompanying adverse yaw? Does the aircraft stop rolling when the input is released to neutral? In pitch, does the aircraft return to the previous attitude? Is there any tendency for the pitch to continue to rise after releasing the stick? Does the pitch attitude continue to oscillate? The same questions apply in the yaw axis. If all is as expected, slow down by 3-5 knots and repeat the process.

At each incremental airspeed point, ensure that you still have nose-down control authority, since that is your most important recovery input. Make note of any changes in response as the aircraft gets slower. For example, it is normal for the aircraft to be more sluggish, but it should still respond positively. Make note of any warning cues, and watch closely for any uncommanded motions. At the first sign of any uncommanded motion (nose rise, nose slice, wing rock, or nose drop), recover the aircraft by lowering the nose, adding power, and increasing speed. Keep in mind that these uncommanded motions are the result of being at a higher angle of attack than previously flown. The most correct initial response is to lower that angle of attack with a nose-down input. Even if the uncommanded motion is a roll-off, the quickest way to stop it is most likely a pitch down, *not* a countering roll input. This can be counterintuitive unless you think about it ahead of time and prepare for it. In fact, a countering roll input without reducing angle of attack could induce further uncommanded motions or departure from controlled flight.

If there are no surprises down to 3-5 knots above expected stall speed, then continue to a complete stall by applying back-pressure on the stick or yoke to slow down the airplane at roughly 1 knot or mph per second. Slowing down more quickly results in a higher nose-up attitude at stall and an overshoot to a lower airspeed. It also doesn't give you time to experience any prestall buffet. Decelerating too slowly, on the other hand, may result in a higher indicated airspeed at stall. The stall warning should occur about 5 knots or mph before the stall itself. Do not depend too much on an uncalibrated stall warning system.

As the airplane decelerates, ensure that the airplane requires an increasingly heavier pull force. If the force lightens or changes to a push force, abandon the test. This may indicate an aft CG condition or a horizontal tail that is not producing an adequate correction; either may cause the nose to pitch up at stall. The continuous increase in stick force with aft deflection is both a stable characteristic and a natural means of preventing inadvertent stall. Once you get to the stall, initiate recovery and record the loss in altitude required to return to level flight. Also make note of aircraft responses during the recovery such as wing rock, secondary stall, or any uncommanded motions. All these observations need to be compared in your post-flight analysis to the expected behavior you had written down before the test.

Some airplanes reach the up elevator stop before the wing stalls. This is acceptable as long as the elevator has the authority to flare the aircraft at its maximum landing weight with the forward-most CG allowed for that weight. Also, at the stall, many airplanes tend to roll toward one wing or the other. This is especially common in homebuilt aircraft because it's almost impossible to build and align the two wings precisely the same without the benefit of expensive construction jigs and rigging tools. A properly designed and rigged airplane will be able to maintain the wings within 15 degrees of level with normal aileron inputs. Make sure you're not cross-controlling the airplane (the slip-skid ball should be centered). If you need excessive aileron or rudder inputs to keep the airplane straight and the wings-level, abort the test. On the ground, assess the airplane for mis-rigging or inadvertent wing twist or asymmetry.

The stall tests are looking to verify the expected behavior. Whenever you run into a result that is different from the expected behavior, at any point in the approach to stall or post-stall, stop, land, and investigate. For example, if the expected behavior predicted buffeting of the airframe 10 knots above stall speed and we don't get any buffet, we may have a problem. Perhaps it's the wing root not reaching stall angle prior to the wingtips; many aircraft are designed to have the wing root stall first because that is what typically causes the early airframe buffet as a natural stall warning. If this is indeed the phenomenon and you elect to continue anyway, you could induce a stall at the tips first and experience a sudden wing roll-off and larger altitude loss in recovery, or worse.

This thorough examination of the aircraft stall behavior not only allows you to properly verify that characteristics match expectations, but also allows you to become intimately familiar with the feel of the aircraft in the slow speed regime. You end up with an aircraft less likely to surprise you and a piloting skill that will keep you out of trouble into Phase II and beyond.

This is one of the more involved flight tests. It examines the airplane in three different configurations (or six, if your airplane has retractable landing gear, because you fly them with the gear up and the gear down), and you fly each configuration three times to reduce the variability in the data. Then you fly the test at four different test weights and CG locations, as indicated on the flight test matrix that opened this section. Start with the forward CG locations.

Before flight, compute each configuration's trim airspeed by multiplying the appropriate estimated stall speed ($V_S$) by 1.5. Write the result on your test card in the appropriate locations. Upon completion of the tests, average the three data points and record them in your POH and on an instrument panel placard.

## Test Card 7 — Determine $V_X$ and $V_Y$

Your airplane's best angle of climb speed ($V_X$) and its best rate of climb speed ($V_Y$) are important, especially when you're figuring your takeoff performance from a short runway surrounded by terrain or obstacles. Fortunately, determining these values is easy, and all you need is time to fly the tests.

Climb tests involve little more than noting your altitude gain at a particular speed every 30 seconds for three minutes. You fly these tests on a heading perpendicular to the wind aloft, testing each speed twice on reciprocal headings to minimize the influence of the wind. Picking a GPS waypoint on the appropriate heading about 100 miles away makes tracking these climb routes easier.

Determine your test speeds before flight by multiplying your airplane's clean stall speed ($V_S$) by 1.1 and 1.5, and subdividing the resulting range by 5-knot or 5-mph increments. Copy the test card and use a separate one for each speed. If, following flight tests at 1.5 times $V_S$, you do not complete the plot described below, you may need to complete an additional series of tests up 2.0 times $V_S$ or more.

After a normal takeoff, climb to at least 1,000 feet AGL. Record the pressure altitude, if possible. Lean the engine as you would for a normal climb, and test the airplane's performance with takeoff flaps as well as flaps up.

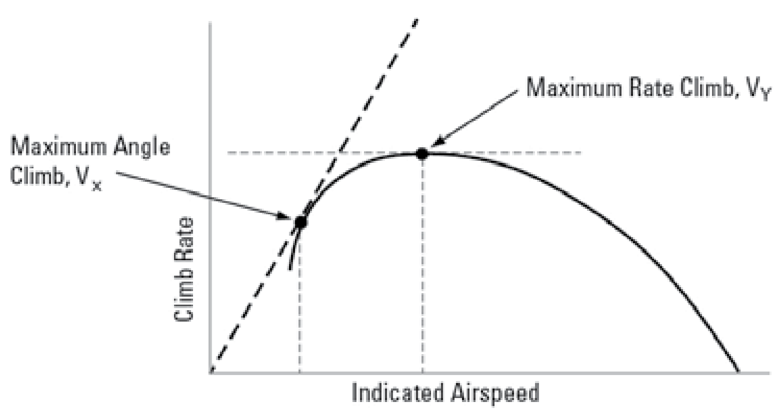
To start the climb, apply full power and pull up to the desired speed. Once the speed has stabilized, start the stopwatch and record the first data points and the subsequent numbers every 30 seconds for three minutes or at least 3,000 feet of altitude gain. Since you're measuring the rate of altitude change, accuracy counts in recording the exact data at the precise time.

After the run, descend to your base altitude and repeat the test on the reciprocal heading. Because aircraft weight affects climb performance, test only one speed per flight. Land and refuel to the original test weight before testing the next speed.

If flying at the aerodynamically determined $V_X$ and $V_Y$ does not provide adequate oil and cylinder head cooling in a sustained climb, calculate the climb rate at the airspeed that maintains proper cooling.

*Calculations and Plotting*

Before converting your data into performance numbers, verify their acceptability. If your results are consistent throughout the climb, the data are good. In other words, you nailed the target climb speed and the altitude gained in consistent blocks. If you deviate more than 3 knots or mph from the target airspeed, or the altitude blocks are of inconsistent size, repeat the test.



With the data validated, use an E-6B flight computer to convert the pressure altitude to density altitude (this allows you to use the resulting performance numbers anywhere). Then plot your data points on an X-Y graph, with the rate of climb on the vertical axis and the speed on the horizontal. If valid, they will form a curve like the sample on the previous page. $V_Y$ is the speed at the top of the curve, and $V_X$ is where the tangent line intersects the curve. Add these speeds to your POH and an instrument panel placard.

## Test Card 8 — Best Glide Speed

What goes up must come down, and if the engine quits you want the best glide speed, which covers the most ground for a given altitude loss. Like the climb tests, this assessment is easy. When flying a course perpendicular to the wind — and its reciprocal — to minimize the influence of the wind, glide at a target airspeed and record the GPS distance traveled every 30 seconds. Pick a waypoint at least 100 miles away that's on your desired course and glide away from it. This reduces the effect of course deviations on the data. As before, precise, consistent aircraft control is the way to yield valid results.

Your target airspeeds are $V_Y$, $V_Y$ plus 10 knots/mph, and $V_Y$ minus 10 knots/mph. Fly the tests in a clean configuration with gear, cowl flaps, and speed brakes retracted as appropriate to your airplane. Copy the test cards and use a separate one for each speed.

After a normal takeoff and climb, level off at the top of your altitude block, at least 7,000 feet AGL. Apply carburetor heat as applicable, pull the power to idle, set a constant-speed prop to coarse pitch (low rpm), and trim the airplane for the target airspeed. When stable on the desired speed, start the clock and note the altitude. Record the exact altitude every 30 seconds thereafter.

Recover after descending at least 3,000 feet*. Climb back to your starting altitude and repeat the test on the reciprocal heading. Aircraft weight will affect performance, so land and refuel before testing the next target speed.

**To ensure your engine is capable of extended idle, work your way up to the 3,000-foot descent by gliding for a series of shorter descents.*

After determining your best glide speed, make a 180-degree gliding turn at that speed, and note the altitude lost. Not only will this tell you more about your airplane's performance, it will give you an idea of the altitude you'll need to glide back to the airport should the engine fail after takeoff.

*Calculations and Plotting*

As with all tests, verify the accuracy of your data before plotting them. If the numbers don't seem consistent from one run to the next, repeat the test. If the conditions are not good, meaning it's windy or the thermals are popping, you will not get good results.

To plot the data, convert each target speed's altitudes and distances into altitude lost and ground covered and record them on an X-Y graph. The speed that covers the most ground for the minimum altitude loss is your best glide speed. Record it in your POH and on your instrument panel placard.

## Test Card 9 — Range and Endurance

Knowing your airplane's range and endurance performance is fundamental to planning safe and enjoyable flights. This isn't limited to simply knowing how much fuel the engine uses; it includes knowing the best speeds to fly when your fuel supply is limited.

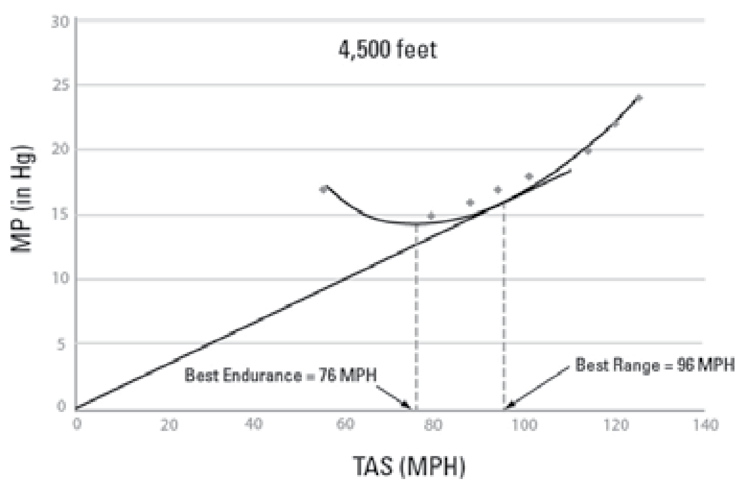
Flying at your airplane's sweet spot, where your engine and airframe are providing peak efficiency, is the key to achieving maximum fuel range safely and comfortably. The engine needs to be run at the best setting for power/gallon/hour, and the airframe needs to be at best lift over drag speed.

Finding the sweet spot involves flying your airplane straight and level at a range of speeds and power settings and noting the fuel flow, altitude, and true airspeed produced by each configuration, the combination of speed and power setting.

Flying full throttle produces the greatest fuel consumption and speed. This defines the top end of the configuration test range. Flying at the slowest possible speed, just above stall, does not give the lowest fuel flow because it takes extra power to overcome the high induced drag in this configuration. Flying on this back side of the power curve is not the speed and power combination that gives the best range.

By plotting the speed and power (rpm or MP) for the range of speeds your aircraft is capable of, you will be able to identify the configuration of fuel flow and TAS that gives you the best endurance in miles per gallon. It's the point on the airplane's drag curve where induced drag is low and parasite drag has not started to increase rapidly. Remember, double the speed, quadruple the parasite drag. The best range speed can be found by drawing a tangent from the origin (0,0) to your plot (see sample to the right).

**Sample Best Range/Endurance Plot**




You don't need to fly every speed and power combination to find the sweet spot. Start your testing at $V_{X,}$ or a bit slower, and then increase your speed in 5- or 10-knot or mph steps. Record the fuel flow for each step and plot the data on graph paper with flow on the vertical axis and TAS on the horizontal. Connecting the data points creates a curve that gives a good picture of the combinations you did not test. If you have a fuel-flow indicator, write down the fuel flows for each test point as well.

Repeat the tests at different configurations and gross weights, from light to maximum, ensuring that the CG is always within its fore and aft limits. To minimize data variations, repeat the test at least twice. Before testing the next configuration, refuel to regain the original test weight and let the airplane cool off if necessary.

Once you know your best endurance and range speeds, you can then determine your fuel flow for each condition. If you have a fuel-flow indicator and you already collected the data during your tests, you can simply refer back to those fuel flows. If you don't have a fuel-flow indicator, you will need to do a little more work.

Using fuel-flow instruments makes this test easier, but you can perform accurate tests without them if your airplane has two fuel tanks. Starting with full tanks, take off and climb to the test altitude on tank A, switch to tank B for the test period of no less than 30 minutes, and then return to tank A for landing. The fuel used from tank B, divided by test time, reveals the rate of flow. (Performing the test in this manner also confirms the accuracy of the gauges that measure fuel quantity and flow.)

If your airplane only has one fuel tank, you need to add a step. Starting with a full tank, take off, climb to your test altitude, set the power for the test, and immediately return to the airport to top off the tank. Record this fuel top-off quantity, and then subtract it from the fuel used on your subsequent flights to test power and speed combinations. For this to work, you must fly the same takeoff and landing profiles as your pretest flight. Climbing to a higher or lower altitude will reduce the accuracy of your results.

Calculating true airspeed is important for accuracy. Remember to record the pressure altitude and outside air temperature on every test flight. Before performing these tests, check that the wings are free of bugs and other contamination.

Before every takeoff, check that:

- Engine temperatures and pressures are okay.
- You have selected a tank with plenty of fuel.
- Before takeoff, fuel is actually flowing from that tank to the engine.

Consistent technique is the key to obtaining repeatable results. Perform the test the same way every time. If the data you collect on any particular flight appears to be significantly different from your expectation, repeat the test.

After compiling the data on speeds, power settings, and fuel flows, make a chart or table and add it to your airplane's POH. See the References & Resources section for articles that provide more details on this test and others.

## Test Card 10 — Takeoff Performance

Knowing your airplane's takeoff performance is key to planning safe departures, especially on short runways and on different surfaces. This test provides that information. You'll record some of the needed data in the cockpit, but to measure the takeoff roll you'll need a ground observer who can see exactly when the wheels leave the runway.

For data on different runway surfaces — grass, gravel, dirt, and pavement — you'll need to perform the test on each of them. Note everything that affects takeoff performance: wind direction and speed, surface type, texture, and slope. You can find the exact runway slope in the FAA's *Chart Supplement*, previously named the *Airport/Facility Directory*. On unpaved surfaces, note the softness, length of the grass, and other appropriate factors.

If possible, use an airport where the observer can parallel the runway and can stick a marker in the ground at the point you take off. With a marker at your starting point, you can measure the takeoff distance with tape measure or GPS. *Note: Only WAAS-enabled GPS will have the accuracy you need.* The pilot can also use runway lights and feet remaining markers to get a measure of the distances.

Repeat the tests at different configurations (as recommended by the designer) and gross weights, from light to maximum, ensuring that the CG is always within its fore and aft limits. To minimize data variations, perform at least two takeoffs in the same configuration and average the data. Before testing the next configuration, refuel to regain the original test weight and to let the airplane cool off if necessary.

The takeoff distances derived by these tests do not guarantee obstacle clearance after takeoff. To get this information, combine the takeoff data with your climb data to determine whether you can clear an obstacle. To account for performance variations caused by environmental factors, such as wind or density altitude, always add a margin of safety to the figures.

Before performing these tests, check that the wings are free of bugs and that the tires are at correct pressures. At high density altitudes, lean the mixture for best power as recommended by the manufacturer, and record the pressure altitude so you can apply the data to similar situations.

Before every takeoff, check that:

- Engine temperatures and pressures are okay.
- You have selected a tank with plenty of fuel.
- Before takeoff, fuel is actually flowing from that tank to the engine.

Consistent technique is the key to obtaining repeatable results. Perform the test the same way every time. To get the quickest acceleration, hold the brakes until the engine is developing full power. If the brakes won't hold that long, release them at the same power setting.

To reduce variation in test results, perform the tests in similar conditions and conduct a series of takeoffs one after the other. Be careful to not overheat the brakes; if you must use repeated or heavy braking, check the brake and wheel temperature and comply with the manufacturer's limits.

After compiling the data, add it to your airplane's POH.

## Test Card 11 — Landing Performance

Knowing your airplane's landing performance is key to planning and executing safe arrivals. This is particularly true on short runways and on unfamiliar surfaces. This test provides that information. You'll record some of the needed data, but to accurately note the rollout distance you'll need a ground observer who can see exactly where the wheels touch the runway and where the aircraft comes to a stop.

For data on different runway surfaces — grass, gravel, dirt, and pavement — you'll need to perform the test on each of them. Note everything that affects landing performance: wind direction and speed, surface type, texture, and slope. You can find the exact runway slope in the FAA's *Chart Supplement*, previously named the *Airport/Facility Directory*. On unpaved surfaces, note the softness, length of the grass, and other appropriate factors.

Naturally, if the designer does not approve or has not tested the design on all the surfaces, you should proceed with caution only after considering all the factors and making thorough preparations. Some builders/pilots choose to limit the runway surface types the aircraft will be operated on. If that is the choice you make, be certain that the POH you produce for your aircraft reflects that decision.

If possible, use an airport where the observer can position him or herself close enough to the runway and can stick a marker in the ground abeam the point where the wheels touch down and where you stop. Determine your rollout distance between these points with a tape measure or GPS.

Repeat the test at different configurations (as recommended by the designer) and gross weights, from light to maximum, ensuring that the CG is always within its fore and aft limits. To minimize data variations, perform at least three landings in the same configuration and average the data. Before testing the next configuration, refuel to regain the desired test weight and let the airplane cool off if necessary.

The landing distances derived by these tests do not guarantee obstacle clearance for landing. To get this information, combine the landing data with your glide data to determine whether you can safely clear an obstacle. To account for performance variations caused by environmental factors, such as wind or density altitude, always add a margin of safety to the figures.

Before performing these tests, check that the wings are free of bugs and that the tires are at the correct pressures. Always record the pressure altitude and temperature so you can apply the data to similar situations.

Before every landing, check that:

- Engine temperatures and pressures are okay.
- You have selected a tank with plenty of fuel.
- Before landing, fuel is actually flowing from that tank to the engine.

Consistent technique is the key to obtaining repeatable results. Perform the test the same way every time. Smooth air and lighter winds are also preferred while performing most of this testing.

Planning the landing approach is important to improve the repeatability of the landing itself. You might want to explore power-off and power-on landings; the use of full, partial, and no flaps; and any drag devices, such as spoilers, applicable to your airplane.

The approach airspeed plays an important role in all landings. Now is a good time to investigate the speeds for use in different situations, such as short runways, soft runways, crosswinds, sloped runways, and aircraft weight. Always keep your tested stall speeds in mind, and do not fly on the back side of the power curve.

Because excessive sink rates can develop at slow speeds, test these configurations at a safe altitude before employing them in an actual landing. A high sink rate, forward CG, and heavy weight may cause you to run out of elevator authority resulting in hard touchdowns with marginal control.

Technique is just as important as the approach speed. You will want to know how the aircraft behaves when the engine is idling or, worse, (simulated) dead. Now is the time to explore and develop the various techniques that you are comfortable with, that your aircraft is capable of, and that your testing shows will yield repeatable results with reasonable pilot technique. As always, explore this behavior at a safe altitude first. Remember the high sink rates and the marginal pitch control when approaching slowly with no prop wash on the tail. To reduce variation in test results, perform the tests in similar conditions and conduct a series of landings one after the other. Be careful to not overheat the brakes; if you must use repeated or heavy braking, check the brake and wheel temperature and comply with the manufacturer's limits.

With every landing, be prepared for a go-around at any time. Execute a go-around as soon as you start thinking about how to "save" a less than adequate approach. A go-around is always the best save. Many perfectly good airplanes are damaged due to failure to recognize the need to reject the landing and go around.

Complete a takeoff checklist for each subsequent takeoff to ensure flaps, trim, and power are all set properly.

*Determining crosswind limits*

The kit manufacturer or designer should have established a maximum recommended crosswind limit for the aircraft. Most POH landing performance charts will provide either a maximum crosswind limitation, a maximum demonstrated crosswind, or both. Testing to determine the crosswind limit is difficult because it is nearly impossible to find real-world crosswind conditions that are stable at the wind speeds of interest for incremental test points building up to a limiting value. However, there is a test you can perform to establish a performance capability limit for your aircraft. The test is a sideslip with constant ground track, and requires a heading gyro and ideally also an attitude horizon. The test will determine the maximum crab angle the aircraft rudder can generate at the planned touchdown speed, which can then be used to mathematically calculate a maximum crosswind capability. Since most GA aircraft perform crosswind landings using the wing-low technique and rudder to straighten the nose to align the wheels with the runway, knowing how much crab you can generate is important.

In flight and at a safe altitude, establish a ground track over a road or section line to provide a reference for the maneuver. Slow the aircraft to normal approach speed and establish the landing configuration at about 10 knots above the aircraft's normal touchdown speed. Note the heading you are using to maintain ground track. Slowly pull the power to idle and descend to maintain airspeed. When in a stable glide with the power at idle, begin a very gradual flare while feeding in rudder and opposite aileron to maintain ground track. Strive to reach about three-fourths rudder deflection* as the speed slows to target touchdown speed and make note of the new heading and bank angle on the heading indicator and artificial horizon. Using three-fourths rudder deflection as a target provides a safety margin in an actual crosswind landing such that there is still rudder travel remaining for steering after touchdown. You now have the aircraft's crab angle capability at the touchdown speed.

**Before you begin this test, which requires employing three-fourths rudder deflection, test for rudder lock using Test Card 15.*

To back-calculate the crosswind component that this crab can neutralize, take the tangent of the angle and multiply by the groundspeed at touchdown to arrive at the crosswind capability. There are two caveats to using this value. The first has to do with the bank angle generated during the test point, particularly for low-wing aircraft. You should measure the aircraft on the ground to determine what bank angle would result in a wingtip contact with the runway with the upwind wheel on the ground and recalculate the angle that would put the wingtip a safe margin off the ground (at least 10-12 inches). Ensure the bank angle generated in the flight test sideslip is less than these measured angles for the geometry of your aircraft. This is generally not a problem for straight-wing GA aircraft, as they don't require large amounts of bank angle to counter rudder sideslip. However, if your aircraft generates enough bank angle to risk wingtip contact with the ground, you will have to reduce the amount of rudder (crab) allowable, and corresponding crosswind allowable, to preclude runway contact.

The second caveat for the crosswind limitation you establish addresses any handling qualities limitations. If the aircraft is difficult to control at higher sideslip angles, then an appropriate limitation needs to be established to ensure that the amount of cross-control you use in a crosswind can be held stable without tendency for pilot-induced oscillations in yaw, roll, or pitch. You can test for this at the same time that you perform the sideslip test maneuver at altitude by observing any handling difficulties in performing the test.

After compiling the data, add it to your airplane's POH.

See the References & Resources section for articles that will provide more information.

## Test Card 12 — Accelerated Stalls

An accelerated stall is an in-flight event that happens at more than 1*g*, often in a steep turn or pullup. Most likely, you experienced this in your flight training by flying a constant bank angle at a decreasing speed until the wing stalled. You'll follow the same procedure for this test.

This test requires a current and proficient pilot. Only perform this test if the designer has performed the test on the prototype and documented that the airplane does not respond poorly. Otherwise, this is truly the domain of a professional test pilot.

**Perform your wings-level stall tests first. Review the techniques described for that test card and apply them here as well. You should have a detailed description of the expected behavior in an accelerated stall available (either from the kit manufacturer or through design analysis) prior to beginning the test. The objective is to verify that the behavior of your aircraft matches the expected behavior.**

Like the wings-level stalls, the accelerated stall test presents the opportunity for loss of control and spins. If you don't feel comfortable flying this test, consider hiring a professional test pilot. If you are not current in this maneuver, fly it with an instructor in an airplane with performance similar to your homebuilt.

Make separate test flights to evaluate the airplane's performance at different weights and CG locations. Start with lighter gross weights and forward CG locations. Never exceed the maximum gross weight or the fore or aft CG limits.

Each test series includes six runs using left and right coordinated turns with the indicated flap settings. If your airplane has retractable gear, run the series with the gear up and down. For each stall, test fly the aircraft at a safe altitude (8,000 feet AGL or as appropriate for aircraft type, in smooth air), trim the airplane to 1.5 times the predicted stall speed, and set the flaps as required for the test (this should be slower than $V_{FE}$).

Apply carburetor heat if required, pull the power to idle, and establish a coordinated turn in a 30-degree bank; ensure the slip-skid ball is centered. Reduce speed to 10 knots or mph above the straight-and-level stall speed for that flap setting, then decelerate at 1 knot or 1 mph per second; you may need to descend gently to maintain this rate.

As the airplane slows, make sure it requires an increasingly greater stick or yoke pull force. If the force lightens or changes to a push force, abort the test. This may indicate an aft CG location or insufficient elevator authority. Either of these may cause the nose to pitch up at stall.

As the airplane slows, normal control inputs should maintain the 30-degree bank attitude and nose position. When you feel the prestall buffet, note the speed, roll level, and recover to straight-and-level flight.

Stalling the airplane is a personal decision that should be based on the wing drop your aircraft exhibited in the wings-level stall tests. Accelerated stalls usually exacerbate this roll, especially when you're turning to the direction of the wing drop. Even a properly rigged airplane may roll up to 60 degrees into the turn or up to 30 degrees in the opposite direction. If the possibility of a roll to 60 degrees is deemed unsafe, do not perform this test.

## Test Card 13 — Trim Effectiveness

You've been using your airplane's trim system since its first flight. This test investigates the trim's authority to relieve control forces in different areas of the operating envelope so the airplane will not require exceptional strength or attention to maintain steady flight under normal conditions.

The test is simple: Trim the airplane for hands-off flight in the configurations given on the test card, from the maximum speed in level flight ($V_H$) with maximum continuous power, to final approach speed with full flaps. Anticipate that slow speeds will require the most nose-up trim and that high speeds will require nose-down trim. Flap and landing-gear extension will have their own requirements.

CG location also affects the trim's authority. A forward CG requires increased nose-up trim, and an aft CG requires increased nose-down trim. In testing the trim at all weights and CG locations indicated on the test matrix, you'll know whether the trim can keep the nose up at a slow speed when the airplane is at maximum gross with a forward CG, or if it can keep the nose down at high speed with a heavy aft CG.

Effective trim is important for more reasons than reducing your workload in cruise. In addition:

- At slow speeds, if an airplane cannot be trimmed to approach speed with flaps deployed, then your workload in the traffic pattern increases.
- If you can trim the airplane for a no-flaps approach speed, trim becomes your backup control in the event of elevator control linkage failure.

If your airplane has aileron and rudder trim, you should test these as well. Many airplanes, however, only have ground-adjustable tabs on the rudder and/or ailerons. They should be approximately set for normal cruise speed before testing.

If a trim system incorporates a spring attached to a cable, push tube, or actuating horn, then control system friction may prevent you from making fine trim adjustments. Eliminating this friction is the only way to make fine adjustments.

## Test Card 14 — Static Longitudinal Stability

Positive longitudinal stability means an airplane returns to its trimmed airspeed after some force causes it to vary from that speed. Measured in safety and pilot workload, this is a desired trait. The resulting change in control force needed to hold an airplane off its trim speed should be a cue to the pilot to make a correction appropriate to the situation.

This control force variation with speed changes should be stable; in other words, while maintaining the same trim position, you have to pull more on the stick or yoke to fly at slower and slower airspeeds and push more to fly faster than the trimmed airspeed.

An average airplane will display the least stability at the edges of its airspeed envelope. At a given speed, pitching moments on the wing and the effectiveness of the tail may result in a decreased pull force as the air-

plane decelerates, or a decreased push force as the airplane accelerates from trim speed.

This test's procedure is similar to trim effectiveness, and you fly it three times, once with heavy forward CG, once with light aft, and a third time at heavy aft CG. Configure the airplane as described on the test card and trim it for hands-off flight, then pull and push the stick or yoke to maintain a 10-knot/mph speed difference, a 20-knot/mph difference, and up to a 30-knot/mph speed difference (or 10 knots/mph above stall speed on the slow side of the test). Then gradually release the control input force and allow the airplane to return to its trimmed airspeed.

If the airplane doesn't return exactly to its trim speed, the most common cause is friction in the control system. The combination of friction and trim position may allow the airplane to "settle" at a lower speed after a pull to slower speeds or a higher speed after a push to faster speeds. Searching for and eliminating the friction is the only solution to this problem.

### Test Card 15 — Static Directional Stability

Directional stability complements longitudinal stability, and its test procedure is similar. Trim the airplane in the configuration indicated on the test card and pick a visual point on the horizon. Keep the aircraft traveling toward this point as you slowly yaw the airplane with rudder input, keeping the wings-level with ailerons. Start the test approximately 500 feet above your target altitude and maintain the test speed with pitch.

Continue adding rudder input until you reach the limit of its travel or are exerting 50 pounds of force (a force higher than would be desirable for inputs near landing or on the runway). Stop at full aileron deflection. Slowly release the rudder input and note how closely the airplane returns to its trimmed condition.

If the airplane remains yawed, the cause may likely be control friction that keeps the rudder from returning exactly to its previous location. If a tap of the opposite rudder pedal corrects the problem, the cause is very likely control friction. If the input does not correct the yaw, investigating the adequacy of the vertical tail and rudder may be in order.

Some rudders may lighten as they approach full deflection. This is acceptable as long as the rudder does not lock in the deflected position. Rudder lock occurs when the vertical fin blocks the air that forces the rudder back to its faired position as the airplane's forward movement and fin orientation diverge. An aerodynamic counterbalance that helps keep the rudder deflected can also contribute to rudder lock.

Yawing an airplane can affect the accuracy of the airplane's pitot-static system. The airspeed indicator will reflect the changing air pressure, especially around the static port. You can estimate the difference by stabilizing the airplane with the deflected rudder, and then quickly and smoothly centering the rudder and returning to coordinated flight at the same power setting. Because it takes time to accelerate after the sudden reduction in drag, any immediate change on the airspeed indicator should be related directly to the pitot-static system.

## Test Card 16 — Static Lateral Stability and Spiral Stability

The ability to roll the airplane with rudder provides valuable information especially if an aileron problem arises. The static lateral stability test assesses this authority. Be aware that rudder effectiveness in this maneuver may change with flap position and airspeed.

To perform the test, trim the airplane in the configuration given on the test card. Establish a 10-degree bank and apply opposite rudder to maintain a constant heading. Once stabilized in this attitude, release the aileron input and attempt to raise the low wing to level flight with rudder input. Perform the test in a left and a right bank.

If the airplane cannot be trimmed in roll, it may be impossible to differentiate the effect of the rudder from the constant rolling tendency. A second test can be performed at 30 degrees of bank at the same conditions as the rudder response test to determine the roll tendency of the aircraft relative to a trimmed bank turn. At 30 degrees of bank, attempt to trim for a hands-off, steady, level turn. Observe whether the aircraft rolls into greater bank, maintains bank, or rolls out of the turn on its own. The result informs you of the tendency of the aircraft to spiral if left unattended during a turn, a very important piece of information, particularly for flight in instrument meteorological conditions.

As you apply rudder, especially at slower speeds, there may be a corresponding pitch reaction caused by the gyroscopic effect of the propeller. As seen from the cockpit, if the prop turns clockwise, left rudder may pitch the nose up and right rudder the nose down. The opposite may happen on counterclockwise engines. Get a feel for the reaction of your airplane before applying rudder with hands free of the stick or yoke.

## Test Card 17 — Longitudinal Dynamic Stability

Even though an airplane exhibits acceptable static stability, oscillations can challenge a design's dynamic stability. Once set into motion, the airplane will continue that motion until its static stability dampens it and the airplane returns to its original, undisturbed condition. If the airplane has insufficient static stability, the motion will continue unabated.

This test evaluates your airplane's long-period dynamic stability by measuring how long it takes to return to level flight from an oscillatory (also known as a phugoid) motion.

After trimming the airplane to the configuration given on the test card, push the stick or yoke until the airplane has stabilized at a speed 20 knots/mph faster than the hands-off trim speed. Then let go of the stick or yoke and count the oscillation cycles it takes for the airplane to regain its trim speed.

After releasing the stick or yoke, expect the airplane to overshoot trim speed and continue decelerating until it reaches a nose-high peak at a speed roughly 20 knots/mph below trim speed. Then it will pitch down, overshoot the trim speed, and then nose up again. The deviations on each succeeding cycle should be smaller,

and a well-behaved airplane barely exhibits any oscillations after seven cycles.

If the speed extremes grow larger instead of smaller with each cycle, the airplane is dynamically unstable — abort the test. This is not necessarily a dangerous condition, as the motion is a low-frequency phenomenon and easily controlled. It is something the pilot needs to be aware of as a fundamental characteristic, however.

During slow-speed dynamic stability tests, make sure the airplane does not pitch to a nose-high stall attitude. If this is about to happen, push forward on the stick or yoke to prevent a stall. If a wing lowers during a cycle, correcting it with a stick input will dampen the recovery and invalidate the results. Pick up the wing with rudder instead.

### Test Card 18 — Runaway Electric Pitch Trim

A growing number of homebuilts have electric pitch trim, and this test evaluates how a malfunction may affect your ability to control the airplane. Naturally, if your airplane doesn't have electric trim, you can ignore this test.

After trimming your airplane to the configuration given on the test card, simulate a malfunction by actuating the trim in one direction and then the other, working up to a three-second test in one-second increments. As you actuate the trim, maintain level flight with the appropriate control input.

After your one-, two-, and three-second trim inputs, evaluate the control forces and any attitude changes that occur before you could correct the situation in a real runaway trim situation. Control forces that may seem acceptable for a short period may not be tolerable for the time it would take to find an airport. Without retrimming, fly a simulated approach at altitude and evaluate the possibility of executing a safe landing. Flaps may positively or negatively affect the control forces at approach speed. Extending flaps will most likely help pitch the nose down.

The test assumes that the pilot is readily able to disconnect the electric trim system. If a cockpit switch or circuit breaker is not within easy reach — and clearly marked — the trim could run to its maximum limits, which might prevent the possibility of continued flight or a safe landing. Locate the electric trim circuit breaker and be familiar with alternate means of stopping runaway trim (such as the master switch or avionics power switch) before flying this test.

# Section Three - Pilot's Operating Handbook

The following format, when completed with aircraft specific data, will complete the requirement of the pilot's operating handbook for your experimental amateur-built aircraft. It will be specific to your aircraft since you are the manufacturer. It is laid out in a sequence that is typical of today's general aviation aircraft.

**1.0 General**

**1.1 Aircraft:** ______________________(Registration)

Make: ______________________
Model: ______________________
Serial No.: ______________________

**1.2 Engine**

Make: ______________________
Model: ______________________
Manufacturer: __________________
Date of Manufacture: ______________________
Serial No.: ______________________

**1.3 Propeller**

Make: ______________________
Model: ______________________

**1.4 Fuel**

Octane rating: ________________
Capacity/tank: ________________U.S. gallons
Unusable/tank: ________________U.S. gallons
Usable/tank: ________________ U.S. gallons

(File Fuel Flow Calculations, Appendix A)

**1.5 Oil**

Brand: _________________
Weight: _________________
Capacity: _________________
Minimum: _________________

### 1.6 Weights

Empty: ________________
Gross: ________________
Baggage allowed: ________________
Baggage with occupants and fuel: ________________

(File Weight & Balance Documents, Appendix B)

## 2.0 Operating Limitations

### 2.1 Stall Speeds

Stall speed at gross takeoff weight: ________________
Stall speed at gross weight with flaps extended ($V_{SO}$): ________________

### 2.2 Flap Extension Speed Range ($V_{SO}$ to $V_{FE}$)

Maximum speed for flap extension: ________________

### 2.3 Maximum Maneuvering Speed ($V_A$)

(Two times $V_{SO}$ =): ________________

### 2.4 Never Exceed Speed ($V_{NE}$): ________________

### 2.5 Wind Limitations

Maximum wind allowed for flight: ________________
Maximum crosswind component at 90 degrees: ________________
(Rule of thumb: 25 percent of $V_{so.}$ Draw chart or graph showing crosswind components at various flight angles, Appendix C.)

**2.6 Service Ceiling:** ________________ (Obtain from kit manufacturer or flight test.)

**2.7 Load Factors:** +________________*g*; -________________*g*. (Obtain from kit manufacturer.)

**2.8 Prohibited Maneuvers**: (Obtain list from kit manufacturer or from design data.)

________________________________________________________________

________________________________________________________________

**3.0 Emergency Procedures:** (Develop aircraft-specific procedures for your airplane and add any additional system failure procedures to the below list as appropriate.)

**3.1 Engine Failure During Ground Roll**

Maintain directional control
Throttle — idle
Brakes — apply
Mixture — idle/cutoff
Ignition switches — off
Master switch — off

**3.2 Engine Failure Below 500 Feet AGL**

Fly the aircraft
Quick check: Air, fuel, spark
If no improvement, then:
Fuel selector valve — off
Ignition switches — off
Wing flaps — as required
Master switch — off
Canopy/door latches — as appropriate
Land straight ahead (Do not attempt to turn more than 15 degrees.)

**3.3 Engine Failure During Flight**

Fly the aircraft
Maintain airspeed: ________________ IAS
Pick suitable landing site
Check: Air, fuel, spark
If unable:
—
Fuel selector valve — off
Ignition switches — off
Wing flaps — as required
Landing gear — as required
Master switch — off
Canopy/door latches — as appropriate
Land aircraft

**3.4 Fire**

**3.4.1 During Start on Ground**

Continue cranking engine.

If engine starts:
Run up power

Normal engine shutdown
Inspect airframe and engine prior to further operation

If engine fails to start:
Mixture — lean
Throttle — off
Fire extinguisher — ready
Mags and switches — off
Fuel selector — off

### 3.4.2 Engine Fire in Flight

Fly the aircraft
Fuel selector valve — off
Master switch — off
Cabin heat and air — closed
Fire extinguisher — activate if necessary (ensure adequate cockpit ventilation)
Land ASAP

### 3.4.3 Electrical Fire in Flight

Fly the aircraft
Master switch — off
Cabin heat — closed
Vents/cabin air — open
Fire extinguisher — activate if necessary (ensure adequate cockpit ventilation)
Land ASAP

### 3.4.4 Cabin Fire

Fly the aircraft
Master switch — off
Cabin heat — closed
Vents/cabin air — open
Fire extinguisher — activate if necessary (ensure adequate cockpit ventilation)
Land ASAP

### 3.4.5 Wing Fire

Fly the aircraft
Electric fuel pumps — off
Navigation and strobe lights — off
Pitot heat — off
Fuel valve — off
Airspeed — $V_{NE}$ if permitting
Land ASAP

**3.5 Electrical/Alternator Failure**

Fly the aircraft
Alternator switch — off, then back on
If alternator is still offline:
Alternator switch — off
Electrical switches — off (except ignition)
Avionics and electrical equipment — off (or on as required)
Flight — terminate ASAP (aircraft is on battery reserves only)

**4.0 Normal Procedures:** Provide information covering the following normal flight procedures, either from the kit manufacturer or create your own:

**4.1** Preflight check
**4.2** Engine start
**4.3** Taxiing
**4.4** Pre-takeoff/run up
**4.5** Normal takeoff
**4.6** Climb
**4.7** Cruise
**4.8** Approach
**4.9** Normal landing
**4.10** Short/soft-field takeoff and landing procedures
**4.11** Balked landing procedures
**4.12** Information on stalls, spins, and any other useful pilot information. Review the spin recovery procedures, and list instructions and recommendations from the kit manufacturer, or create your own.

**5.0 Performance**

**5.1 Takeoff and landing distances**

Takeoff: ________________
Landing: ________________

(Correct to standard conditions: sea level and 59 degrees Fahrenheit.)

**5.2 Rate of Climb:** ________________ (See Appendix C)

**5.3 Cruise speeds:** File graph or chart of cruise speed conditions at various altitudes and power settings, obtained from flight test cards.

**5.4 Rpm range:** Obtain from engine or propeller manufacturer.

From ___________ rpm to __________ rpm
Critical rpm: ___________

**5.5 Fuel Consumption:**

Calculated at recommended cruise altitude and power setting: ________________
Measured at following conditions: ________________

**5.6 Additional Notes or Comments:**

________________________________________________________________________

## 6.0 Weight & Balance Information

**6.1 Installed equipment list:** Add separate list of equipment installed but not included in the weight and balance calculations.

**6.2 Center of gravity (CG) determination and range:** File weight and balance documents (Appendix B).

## 7.0 Aircraft Ground Handling and Servicing

**7.1 Servicing fuel, oil, and/or coolant:** List instructions from kit and engine manufacturers, or create your own instruction list.

**7.2 Towing and tie-down instructions:** List instructions from kit manufacturer or create your own.

## 8.0 Required Placards, Markings, and Flight Documents

**8.1** Insert list of required placards for your particular rules of operation as determined by your regulatory agency.

**8.2** Ensure all instruments have the necessary operating range markings as recommended by your kit or engine manufacturer and regulatory agency.

**8.3** Ensure your registration call sign is affixed to your aircraft in accordance with your regulatory agency.

**8.4** Ensure all restricted flight operations are clearly placarded in view of pilot as required by your regulatory agency.

**8.5** Ensure all required flight documents are on board as required by your regulatory agency.

**9.0 Additional Supplementary Information:** Insert as required.

# Section Four - References and Resources

Listed by section are the references and resources drawn upon to create this manual that can provide any extra information you desire. Many of the resources are articles from *EAA Sport Aviation* magazine. Some of these articles are available in the Homebuilder's Headquarters section of the EAA website (www.EAA.org/homebuilders). A greater resource is the *EAA Sport Aviation* archives (www.EAA.org/sportaviation), which gives you access not only to the articles listed here, but also to every article published since 1953's Issue 1, Volume 1, all of which are searchable.

Many of the FAA documents are also available on the EAA and FAA websites. For searchable access to all FAA handbooks, manuals, documents, orders, and regulations, consider purchasing a copy of the Summit Aviation Computerized Aviation Reference Library (visit www.SummitAviation.com for more information).

Please send all corrections, comments, and suggestions for improvements to FTM@EAA.org.

## Pertaining to Section One — Aircraft Preparation

**Record-keeping**
FAA AC 43-9C *Maintenance Records*
FAR Part 43

**Weight & Balance**
Hiscocks, Richard D., *Design of Light Aircraft*, Vancouver, British Columbia, Canada, 2002.
*Aircraft Weight and Balance Handbook*, FAA Handbook 8083.1

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### Pertaining to Section Three — Pilot's Operating Handbook

Specification for Pilot's Operating Handbook: GAMA Specification No. 1; https://gama.aero/facts-and-statistics/publications/gama-and-industry-technical-publications-and-specifications/

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