Flying The Beech Bonanza

Second Edition

by John C. Eckalbar

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Aircraft Technical Book Company, LLC
http://www.ACTechbooks.com
(970) 726-5111

Library of Congress Catalog Card Number 97-62270

ISBN 978-0-9616544-3-6 (Hardback)
ISBN 978-0-9616544-3-6 (Paperback)

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Introduction

There are two prerequisites to becoming a good Bonanza pilot—one relating to skill and the other to knowledge. First, you have to develop the skill to get the airplane to do what you want. Second, you must acquire sufficient aeronautical knowledge to want the airplane to do the right things in the first place. Let me elaborate.

The first type of ability, getting the airplane to do what you want it to, primarily involves physical dexterity and hand-eye coordination. At this stage we develop a "feel" for the airplane, exhibiting enough finesse with the controls for smooth, coordinated approaches and landings. The Bonanza is designed well enough that these sorts of operations are, with practice, soon done gracefully by any pilot of average ability. Years of Bonanza experience might instill in us a feeling for the characteristics and rhythms of the airplane that no book could pass on, but even this level of "feel" is but a small part of what it takes to become a good Bonanza pilot.

The second prerequisite, that of knowing what the airplane ought to be made to do in any situation, is not learned even from years of routine experience in the airplane. Instead, it is primarily learned by hours of quiet study at home. For instance, you may have legendary skill with the yoke and yet be at a total loss when it comes to picking the speed for maximum range in a low fuel emergency or determining the proper weight-adjusted speed for rough air penetration. These operations have nothing to do with "feel," finesse, or coordination, and they are not outlined in so many words in the *Flight Manual*. Knowledge of the proper speeds comes from careful study of aerodynamic theory and application of the results to the specific airplane. That means it takes some book work and some *systematic* exploration of the Bonanza's flight characteristics to become a good Bonanza pilot. This book is designed to help.

I think that your safety in the Bonanza is directly proportional to your willingness to make a science of your flying strategy, your willingness to make Bonanza pilot technique a sub-specialty, second only to your profession. But the problem you encounter, even if you

are willing to do this, is that there is no readily available source book. It is true that there is more written on the Beech Bonanza than any other general aviation airplane, but amazingly, there is no book dedicated to exploring the Bonanza's flying characteristics. Larry Ball's *Those Incomparable Bonanzas* (McCormick-Armstrong Company, Wichita, 1971) is an excellent book about Bonanza history and model variations, and it should be on every Bonanza pilot's shelf. Norm Colvin's *Colvin's Clinic* (McCormick-Armstrong, Wichita, 1984) puts years of Bonanza maintenance experience in the hands of every pilot and should be required reading. The Beech Pilot Operating Handbook (POH) and Airplane Flight Manual certainly has a lot to say about flying the Bonanza; but while it is quite comprehensive in its presentation of performance data and check lists, it is altogether silent on a number of important operational items like short field takeoff technique, stall characteristics, maximum range speeds, and many other areas. Last, but by no means least, the Bonanza pilot is fortunate in having over one thousand pages of shared Bonanza experience packed into the cumulative issues of the American Bonanza Society's *Newsletter*. These unique documents are a must-have item for any serious Bonanza pilot. Where else can one get so many first hand accounts of diverse Bonanza phenomena like ditching, flying in ice, or mixture distribution patterns. But still, none of these books is dedicated solely to improving one's Bonanza flying skills.

This book is intended to complement, not compete with, the other books just mentioned. There is nothing here, for example, on the model to model evolution of the Bonanza or on systems *per se*. This is a book on "stick and rudder" for the Bonanza. In fact it is very close in its intent to Wolfgang Langewiesche's classic *Stick and Rudder* in that it is not a comprehensive text on flying—there is nothing here on weather or navigation, for example—it is instead about the development of proper technique for handling an airplane.

The present book asks a lot of the reader. You are expected to follow the logic of some classical aerodynamic derivations, and perhaps do some algebra in the margins, or even some calculus in the optional appendices. And in addition, numerous flight experiments

are suggested, each one designed to reveal some important characteristic of the Bonanza. For instance, every pilot knows that getting maximum miles per gallon from the remaining fuel sometimes becomes the pilot's paramount objective. Most manuals, including the Bonanza manuals, don't offer a clue about how to do this. In this book we carefully examine the theory behind maximum range flight and see that max range at any given weight occurs at a single indicated airspeed, which is valid for all altitudes. This speed maximizes the lift/drag ratio and is called $V_{L/Dmax}$. We then outline a simple in-flight experiment which will reveal $V_{L/Dmax}$ for your Bonanza. We further show theoretically how to adjust this target airspeed for variations in weight or headwind.

Some may feel that all this is too theoretical and technical, but it is my feeling that safe flying demands knowledge of and respect for certain fundamental facts from aerodynamics. And it is my belief that Bonanza pilots recognize the truth of this and would be willing to do the requisite homework if only they would be offered some guidance. In fact that is the sole purpose of this book.

So no apology is offered for the difficulty of some sections of this book. I have made an effort to hold the technical-mathematical content to a minimum, but if there is an important fact (like the propositions regarding Va or $V_{L/Dmax}$) that cannot be understood any other way, then I have no hesitation about leading the reader into (and hopefully out of) whatever technical-mathematical thicket is necessary for a reasonably full understanding.

Consider this: The U.S. Navy uses the T34C as its basic trainer. With some oversimplification, this is essentially a 4300 pound Bonanza with a Pratt & Whitney PT6 turbine engine. Most general aviation pilots would think of the T34C as a fairly "hot" airplane, rather than a trainer. Yet the typical Navy pilot will solo a T34C after only 26 hours dual. How is it that the Navy succeeds in starting its pilots in such an advanced airplane? A part of the answer is that before the Navy Cadet ever sets foot in the "Bonanza," he or she must complete an intensive 14 week ground school including, among other things, a fairly sophisticated course in aerodynamics. Even a cursory look through their text, *Aerodynamics for Naval*

Aviators, demonstrates that the Navy expects more aerodynamic understanding from its pre-solo cadets than the FAA requires of a flight instructor or even an Airline Transport Pilot applicant. And this was true even during the Second World War, when the Navy was trying to turn pilots out "in a hurry." Apparently the Navy feels that a thorough grounding in aerodynamics is a *sine qua non* for a competent aviator. The surprising thing is that anyone else should think otherwise.

The layout of the book is as follows: In Part I we begin by exploring some facts about the external characteristics of the various basic Bonanza types, i.e., 35-B35, C35-V35B, 33-G33, 36-A36, B36TC. Included is a fairly careful analysis of the NACA 23000 series airfoil, which all Bonanzas use. What we are looking for are design features that have important operational implications. There is a fairly exhaustive discussion of the Bonanza maneuver-gust envelope, with much space given to the determination of weight-adjustments for Va. The chapter on handling qualities is concerned primarily with stability characteristics, stick forces in various regimes, stall qualities, and trim effects. We give a particularly thorough examination of lateral (spiral) stability. Finally, we include a chapter on aerodynamics of the V-tail, since most other sources available to the Bonanza pilot have barely any mention of the V-tail.

In Part II, we have a chapter given to each of the basic phases of flight, including a full chapter on instrument operations "by the numbers." We give particular attention to items which are not well covered in the Beech manuals, such as use of flaps on takeoff, leaning by EGT, and use of various speeds for enroute climb.

Part III is a fairly methodical treatment of weight and balance issues for Bonanzas. In the chapter on weight, we go through the various formulae for predicting performance changes with weight. There is a separate chapter on the theoretical implications of cg, including stick force changes in Bonanzas and stall/spin recovery differences for fore and aft cg's. Finally, we have a chapter covering the major loading issues for the various models.

The section on emergencies focuses primarily on problems not covered in the flight manuals. If the engine catches fire in flight,

follow the Beech check list in the Emergency Procedures section. I have nothing substantial to add to that. But there is much to be said here about developing a strategy for maintaining control in turbulence. For instance, what speeds and configurations work best? We also look into the theory and practice of flying for maximum range and the determination of the minimum safe turn-back altitude in the event of an engine failure on takeoff. Some occasionally fatal non-emergencies, like a door latch failure, are also covered.

The postscript gives a final wrap up on Bonanza speeds. There is a proper speed for every operation, and it is my contention that fifty percent of safe Bonanza technique consists of knowing the speeds and being able to smoothly configure the airplane to achieve those speeds. Some final hints are offered.

This project has benefitted substantially from the help and suggestions of many people. Foremost are my fellow American Bonanza Society Pilot Proficiency Program flight and ground instructors—Sam James, Ken Pearce, John Howard, Bill Hale, Hank Canterbury and MacKenzie Patterson. I have learned more about Bonanzas over lunch with this group than I have learned from all other sources combined. Thanks are also due to: Cliff Sones, former Administrator of the American Bonanza Society; Frank Ross, former ABS President; Ottis Cameron of Alcor; Continental Motors; Bruce Augustus; Al Strickfadin; Karen Kister; Roxanna Glang-Nairz; and Walter L. Eckalbar, Jr., my father, flight instructor, and flight data recorder. And special thanks to Paul Bowen for all of the beautiful Bonanza photos.

Two important caveats are in order before we get to the text. First, this book reports on many in-flight experiments having to do with airspeeds, power settings, climb rates, etc. These results were gathered from flying a very large sample of typical Bonanzas from the fleet. And though my results are no doubt reasonably accurate for the representative Bonanza, I cannot claim perfect accuracy in all applications. There are several reasons for this, but most important is the fact that no two Bonanzas are exactly alike. They differ in propeller blade efficiency, actual engine power output, rigging, and external aerodynamic modifications such as gap seals and tip tanks,

etc. So what is true for one Bonanza's performance need not be exactly true for all others. In addition, all of our results were obtained in aircraft with standard, factory installed, engine and pitot-static instrumentation, which is subject to error.

The second caveat is this: There is nothing in this book, either on or between the lines, which advocates operating the Bonanza contrary to the limitations printed in the Pilot's Operating Handbook and FAA approved Airplane Flight Manual. I hope the reader finds this book a useful supplement to the POH, but it is in no way intended to be a substitute.

Photo courtesy of Paul Bowen. This and all subsequent photos are copyrighted by Paul Bowen.

1. The Bonanza's External Characteristics

In this chapter we are concerned with some of the essential external features of the Bonanza. We are not interested in the evolution of cosmetic details such as window sizes or tail cone shapes, instead we focus here only on those external features which have some fundamental aerodynamic importance. Specifically, we consider the wing, the tail, the manner in which the model 36 was "stretched," etc.

Wings

All of the Bonanzas have essentially the same wing. It is derived from the NACA 23000 series airfoil—specifically, a 23016.5 at the wing root and a 23012 at the tip. Both airfoils have their maximum camber located 15 percent of chord aft of the leading edge. The 23016.5 has a thickness equal to 16.5 percent of the chord, and the 23012 is thinner with a thickness of 12 percent of chord. The airfoil was developed in the mid 1930's and has been a favorite of designers ever since. It was in fact chosen for the Piper Malibu. The popularity of the airfoil derives from the fact that it has relatively high lift and low drag together with a low pitching moment coefficient.

The 23000 series airfoil also has a rather abrupt drop in lift coefficient as the stalling angle of attack is reached. Figure 1.1 compares the coefficient of lift versus angle of attack curves for the NACA 23012 and NACA 65_2-415 airfoils. The latter is used on the Piper Cherokee, an airplane noted for its gentle stall. Notice that when the stalling angle of attack is reached on the 23012 airfoil, lift falls precipitously, whereas lift drops gradually after the stall on the 65_2-415 airfoil. The chapter on handling qualities will have more to say on this point.

The wing incidence is four degrees at the root and one degree at the tip. This is called "wash-out" and is a standard design technique used to insure that the stall progresses from the root to the tip, with some aileron effectiveness and some stabilizing lift at the

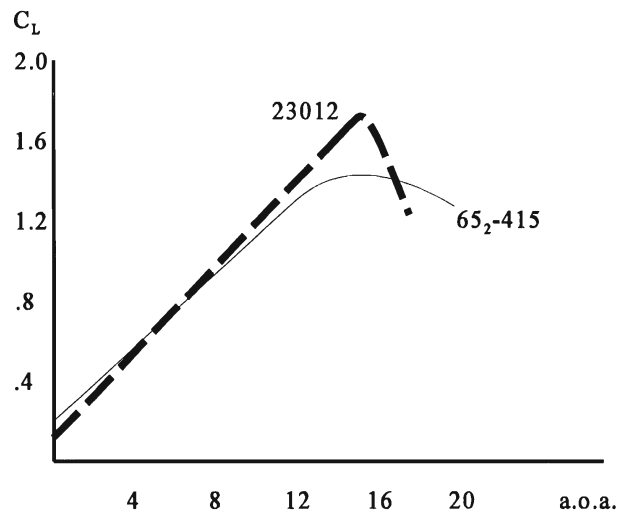

Figure 1.1. Angle of attack and coefficient of lift for two airfoils.

tips early in the stall progression.

The wing tips have changed over the years—the first significant change being the squared tips of the M35 and later Bonanzas. These added a little more than seven inches to the wing span and 3.3 square feet to the wing area. Internal structure and wing skin thickness have also changed over the years, but it is only the external features of the wing that interest us here.

The wing of the B36TC has two significant differences from earlier Bonanzas. First, its span is longer by four feet four inches, giving it a greater wing area and higher aspect ratio. This improves climb and high altitude performance generally. Second, it has dual vortex generators (triangular wedges) on the leading edges of the wings. The story behind the vortex generators is told by Beech engineer Dennis Crider in "Development of Wing Leading Edge Vortex Generators for a Single Engine General Aviation Airplane" (SAE Technical Paper Series, no. 830770). Briefly, the prototype B36TC did not meet the spin recovery criterion for certification, since

it took more than one additional turn to recover from a one turn spin. Beech tried a number of aerodynamic modifications to cure the problem, including ventral fins, nose strakes, and blade-type vortex generators mounted on the fuselage ahead of the wing root. In the end, Beech elected to use the dual wing vortex generators together with an increase in elevator down-travel (to help reduce angle of attack more quickly in stall-spin recovery). According to Crider, the theory behind the vortex generator is that "the vortex produced by the junction isolate(s) the air flow over the wing outboard of the vortex, thus allowing the isolated panel to remain flying to a higher than normal angle of attack." (p. 2) The effect is to preserve lift at the wingtips, to dampen roll when the inboard wing is stalled, and to preserve aileron effectiveness. The same vortex generators are also placed on the post-1984 A36 and F33C.

We will have more to say about lift and the Bonanza wing in the chapters on Center of Gravity and the Maneuver-Gust Envelope.

Tails

Of course, the most obvious external difference between Bonanza models is the tails. There are three basic designs. The original V-tail on the Straight 35 to B35 had a dihedral angle of 30 degrees, a chord at the root of about 42 inches, and a chord at the tip of about 31 ½ inches. All Bonanza ruddervators and horizontal stabilizers have about the same span—68 inches. Starting with the C35, all subsequent V-tails had a dihedral of 33 degrees and root and tip chords of about 50 ½ and 35 ½ inches, respectively. The horizontal tail of the 33 and 36 series Bonanzas is very similar in its external dimensions to the original small V-tail. The vertical tail of the 33 and 36 series Bonanzas has an area of about 15.3 square feet.

Geometrically, though perhaps not aerodynamically, the V-tails can be "projected" to give their vertical and horizontal "equivalent areas." This means, for instance, that if we placed an old V-tail directly below a distant light source and traced the tail's shadow on a horizontal plane, we could measure the horizontal component of the V-tail. The area of this shadow would be the

"equivalent horizontal tail area." Similarly, a light from the side would cast a shadow on a vertical plane (paralleling the longitudinal axis), and the area of this shadow would be half the "equivalent vertical tail area." (It is half, since there are two tail members.) Table 1 gives the data for the various tails.

Table 1
Equivalent Areas

Tail	Old V-Tail	New V-Tail	Conventional
Horizontal Tail	31.9	36.4	38.0
Vertical Tail	18.4	23.6	15.3

Measurements were obtained by the author with rather casual use of a tape measure, and are only roughly accurate. Several patterns are apparent: First, the new V-tail and the conventional-tail Bonanzas have roughly equal horizontal tail areas, and this is in accord with their very similar pitch stability characteristics. Second, the new V-tail has quite a bit more "vertical tail area" than the old V-tail, and this translates directly into improved directional stability. The new V-tail seems to dampen the Bonanza's yaw oscillations about 30 percent faster than the old V-tail. (More will be said about this in the chapter on handling qualities.) Third, the conventional tail has less (equivalent) vertical tail than either of the V-tails, but the design is inherently more effective, so no direct yaw stability implications can be made. Fourth, the wetted area (i.e., exposed surface area) of the conventional tail is about 102 square feet, compared with about 81 square feet for the larger V-tail. The result is that the wetted area of the 33 series Bonanza is about 3 percent higher than that of the 35 series—about 640 vs. 620 square feet. By comparison, I estimate the wetted area of the A36 to be about 655 square feet. As we shall see shortly, drag depends in part on total wetted area.

The A36 Stretch

The A36 is ten inches longer than the F33A. The forward fuselages are identical, but the aft fuselage of the A36 is stretched. This longer fuselage is then located over the wing in such a way that all of the extra length lies ahead of the wing. That is, the propeller is ten inches further from the wing's leading edge on the A36 than on the F33A. And the distance from the trailing edge of the wing to the leading edge of the tail is the same for the A36 and F33A.

This mode of stretching the fuselage and relocating the wing has several implications. First, the center of gravity of the empty A36 is further forward (in relation to the wing) than that of the F33A. A comparison of the basic empty cg's of the two airplanes in the sample problems in the Beech Handbooks shows the cg of the A36 is 3.6 inches ahead of the F33A's, where both are measured in relation to the wing. This has important implications for weight and balance control, and these are taken up in a later chapter. Second, the length of the wheelbase of the A36 is ten inches longer than that of the F33A. This gives some improvement in stability on the ground, but is hardly noticeable in view of the F33A's already good manners. Third, since the pilot sits ten inches further forward over the wing on the A36, the view down is less obstructed. The difference is enough to notice and is a worthwhile improvement in its own right.

Deck Angle on the Ground

As a Bonanza sits on the ground, the nose is pitched up approximately 3.5 to 4.5 degrees, i.e., the angle between the longitudinal axis and the ground is 3.5 to 4.5 degrees. The lesser figure is for the A36 and the higher figure for the V-tailed Bonanzas. Both figures will be somewhat higher when the aircraft is loaded aft and the nose gear shock strut is extended.

This has several implications. First, unlike some airplanes which sit on the runway in a nose-low attitude, the Bonanza will fly itself off from a three point attitude on takeoff. This, however, is not the recommended procedure, as we will see in the chapter on

takeoffs. Second, the pilot should never set the airplane symbol in the gyro horizon at zero (i.e., on the horizon) while the airplane is on the ground. The airplane symbol should be "zeroed" only in level cruise flight. This is particularly important if the pilot flies "by the numbers." For instance, the pilot may habitually pitch the nose up ten degrees for the initial climb. But if the horizon is set at zero on the ground when the airplane is actually five degrees nose up, then when the pilot pitches the airplane to an indicated ten degrees nose up, it will actually be fifteen degrees nose up—and this is potentially dangerous.

Overall Skin Friction Coefficient

Most pilots appreciate that the Bonanza has an aerodynamically clean design, but it is interesting to see objectively just how clean the airplane is. Table 2 lists the overall skin friction coefficients for a variety of aircraft. The skin friction coefficient is a function of the shape of the object, its smoothness of surface finish, the existence of handles, steps, and gaps along doors, windows, flaps, gear wells, etc. How clean is a Bonanza? About midway between a P-38 and a Lear 25.

Table 2

Airplane	Skin Friction Coefficient
Cessna 150	0.0100
PA-28	0.0095
PA-28R	0.0067
P-40	0.0060
P-38	0.0054
V35	0.0049
Learjet 25	0.0042
P-51F	0.0038
F-104	0.0032

When the skin friction coefficient is multiplied by total wetted area of the airplane, the result is the "equivalent flat plate area" or "parasite area" of the airplane. Darrol Stinton estimates the wetted area of the V-tail Bonanza to be about 620 square feet, so the equivalent flat plate area is just over 3 square feet—a square with sides of less than 21 inches (*The Design of the Airplane*, p. 213). (Source: Barnes W. McCormick, *Aerodynamics, Aeronautics and Flight Mechanics*, p. 198.)

Photo courtesy of Paul Bowen.