FLY THE WING

A Flight Training Handbook for Transport Category Airplanes

Billy Walker | **FOURTH EDITION**

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Aviation Supplies & Academics, Inc.
Newcastle, Washington

Fly the Wing: A Flight Training Handbook for Transport Category Airplanes
Fourth Edition
by William D. "Billy" Walker, Jr.

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See the ASA website at www.asa2fly.com/reader/flywing (password: asaflywing) for additional resources and downloadable materials.

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Dedication

The fourth edition of *Fly the Wing* is dedicated to the memory of the late Captain Jim Webb.

—Billy Walker

Jim Webb, before his death, was a retired Eastern Airlines captain. He learned to fly with a barnstormer at the age of thirteen. For fifteen years he worked as an Eastern Air Lines flight instructor and check pilot. During that period he trained almost 500 pilots, with no failures and well above average results. He also conducted rating rides, proficiency checks, and instruction and checking in simulators. During World War II he was a B-24 pilot in the Central Pacific, flying thirty-three missions and earning two Distinguished Flying Crosses and four Air Medals. After the war, Webb flew a variety of charter and corporate planes before joining Eastern. He logged more than 35,000 hours in the cockpit of all types of aircraft.

Contents

Foreword

Those familiar with *Fly the Wing* know it as a well-known and respected airline training text. It is considered a "must" read for all aspiring and current airline pilots. Looking back over my own flying career, I've found myself returning to the text of *Fly the Wing* prior to job interviews or initial aircraft ground schools. Each time I read the text, I gleaned additional useful nuggets of information or flying techniques that have enabled me to become a better pilot. For this reason, I have always been a big fan of *Fly the Wing* and have recommended the book to many pilots.

Fourteen years after the second edition of *Fly the Wing* was published, it became apparent that there was a need for an updated third edition. Sadly, Captain Jim Webb had flown west a few years prior, and it seemed that *Fly the Wing* would eventually fall out of print. Recognizing this fact, Iowa State Press [Blackwell Publishing] asked Captain Billy Walker if he would update the book, continuing the fine legacy begun in the first two editions. In this regard, Capt. Walker has succeeded admirably.

The most obvious change implemented for the third edition was the addition of an accompanying training CD-ROM. For the new fourth edition, the CD-ROM contents are now available online from the dedicated Reader Resource page. This online Reader Resource webpage contains a tremendous amount of reference material, including a *Honeywell Flight Management Systems Pilot Guide* and an Airbus A320 *Quick Reference Handbook*. The online Reader Resources are referenced throughout the textbook to further illustrate a technique or procedure. These guides will prove to be a tremendous resource for any pilot transitioning to a transport category aircraft. Throughout the book, material reflects current airline operating procedures and Federal Aviation Administration regulations. These additions to *Fly the Wing* are sure to make this text an invaluable source of aviation knowledge for a new generation of aspiring pilots.

—Mark J. Holt

Acknowledgments

The late Captain Jim Webb; Virginia Webb; the late Captain Ralph S. Johnson, Chief Test Pilot, United Airlines; the late W. D. "Pic" Walker; Captain Mark Holt, author and aviator extraordinaire; John Lauber, VP Airbus; and Captain Al Spain, VP Operations, JetBlue Airways (Ret.). Former Frontier Captains David P. Kaplan, the late J. David Hyde, and the late Captain Robert L. Williams had much input to this book. To all I am grateful.

About the Author

Captain Billy Walker retired in 2001, because of the Age 60 Rule, as the senior JetBlue Airways line captain. Until 2007, he was the senior test pilot, instructor, and check airman with JetBlue Airways. He administered ATP and A-320 type ratings as an FAA Aircrew Program Designee (APD). Walker is an avid fly fisherman and in his free time stays busy flying out of Airbase Arizona (CAF). For many years, Walker flew the North American AT-6/SNJ as well as an AC-47 Gunship based at Falcon Field, Mesa, Arizona.

Walker learned to fly as a youngster flying with his pioneer aviator father, the late W.D. "Pic" Walker, 1992 National Aeronautic Association Elder Statesman of Aviation. "Pic" was a founding member of the Civil Air Patrol. His company, Plains Airways, trained more than 10,000 pilots and mechanics during World War II. Walker's mother, Frances Emily Walker, was the first woman to learn to fly in Wyoming during the 1930s.

Walker flew for the historic Frontier Airlines for two decades and then became an instructor, check airman, and FAA examiner with America West Airlines (AWA). He was with AWA for 11 years until joining JetBlue Airways as part of the start-up team. He has written numerous technical publications and aviation articles.

During the Vietnam War, Walker was on a leave of absence from Frontier in 1971–1972. He was based out of Pochentong Airbase, Cambodia, with Air America (Tri9). Returning to the left seat at Frontier, he flew everything from DC-3s, DHC-6s, Convair 580s, Boeing 737s, and MD-80s. He was involved in several General Aviation companies, as well. Walker is Airline Transport Rated and is a commercial hot air balloonist. Additionally, Walker is a Certified Flight Instructor with CFI/II ASMEL, Ground Instructor, and certified repairman endorsements, along with having numerous type ratings on his certificate. He is in the aviation business for the love of the game.

To learn more about Billy Walker, visit www.CaptainBillyWalker.com.

Introduction

By Jim Webb

Flying an airplane—any kind of flying: joyriding, aerobatics, military flying, flying for hire, and particularly instrument flight—is a form of human expression. A pilot's skill, the manner in which the flight is planned and executed, and regard for safety are revealing personality traits.

Many of the pre-employment procedures used by airlines to test pilot applicants and to screen them thoroughly before putting them into the cockpit may be totally unrelated to flying. Though these procedures are sometimes unfairly criticized by those already in the cockpit, they are designed solely to determine if the applicant has sufficient maturity and stability to become an airline captain. Airlines never hire copilots only—at least not intentionally. They seek captain material. In addition to aviation experience and background, they examine ability to learn, to adapt, and to exercise the qualities of judgment and command that the left seat requires.

To fly demands that one adapt to a new three-dimensional environment, learn the vagaries and capricious tendencies of weather and meteorological phenomena, acquire knowledge of the atmosphere, and develop skills and techniques of control manipulation to make the craft respond smoothly and safely. The pilot must also know and thoroughly understand the complex systems and operational limitations of the craft as well as the limitations of personal skills and abilities so that the bounds of either are never exceeded. The pilot must learn the science of navigation and radio aids to navigation; develop self-discipline to accept the responsibility of command and to exercise the degree of judgment the profession requires; and learn to project forward in both time and space to stay ahead of the speeding aircraft in thinking and planning and thereby base decisions and actions upon an extension of the position in flight to a predicted position in time and space to adequately cope with the situation presently at hand.

These technical skills, this required knowledge, and the ability to exercise command judgment are not easily acquired. They come only from experience, good training, and constant practice. Because this is true, they are things that really cannot be taught. Pilots themselves must learn by analyzing every maneuver and phase of flight for desired performance; by striving constantly to improve both their technique and judgment through practice; and by being honestly self-critical in evaluating their mistakes.

I don't believe any flight instructor in the world can actually bring a pilot to a high enough degree of proficiency in these factors to meet the qualifications of an airline captain. The instructor can offer advice, demonstrate various maneuvers, criticize, and impart knowledge and skill; but the acquisition of that knowledge and skill must come from the students. They must learn first how to recognize their own mistakes and shortcomings, then how to correct them quickly and smoothly; therefore, they must teach themselves to a great degree—taking the instructor's advice and help into account—and acquire the necessary skill and ability through their own efforts.

Since flying is a form of self-expression, it may be compared to another form—music. A music teacher can teach the fundamentals, show students how to play the piano, and teach them to read music, but cannot teach them how to play the piano. The instructor can only guide; learning to play must come from a student's motivation and desire to acquire the skill, and success comes in direct relation to the amount of effort put forth to achieve it.

As they progress from the fundamentals, pianists develop their own style of playing. No two concert pianists play exactly alike, yet each may very well be recognized as a master of the instrument. And so it is with pilots. No two persons think alike, or react alike, or express themselves in an identical manner; but each—with a skill based on the same theories of flight, aerodynamics, and aeronautical sciences—may well be a master pilot. In every case they must first learn the fundamentals well and then polish and refine their skills as they go on to more difficult maneuvers and advanced phases of flight.

This creates a very frustrating problem for flight instructors. When a student does an outstanding job in the oral examination and check ride, it is attributed to skill, knowledge, and individual ability. This is as it should be. The student really deserves the credit. But if one does poorly or fails the oral examination or flight check, then it is charged to the instructor for not teaching the fundamentals, not teaching the student the procedures, and not properly preparing the student for the check. And woe unto the instructor who has several below-average students in a row! The FAA soon begins to look critically at that instructor.

Very rarely do airline flight instructors receive any thanks. Their job is to see that the students receive a rating in the aircraft. To do this, an instructor patiently and painstakingly tries to eliminate a student's weak spots and endeavors to train the applicant to a degree of proficiency that will instill the confidence needed to pass the check. The instructor's only satisfaction comes from seeing the student's success.

The instructor gets a share of criticism, though. I've seen many instances of students doing a below-average or failing check ride and then criticizing their instructor, the check pilot, the FAA inspector, and the entire training department for their own display of poor airmanship. These severe critics of the training program almost invariably are of two distinct types.

The first type goes to the training center without any preparation whatsoever—hasn't opened the aircraft manual since ground school, hasn't taken time to study the performance section, has taken no interest in reviewing normal operating procedures and emergency procedures, and hasn't even looked at the training section of the manual to learn the profiles of the various maneuvers to be performed. In other words, this type hasn't even tried to learn the memory items that are required and can be learned—before ever flying the airplane—right out of the book. This type seems to think that an instructor can bore a hole in the head, pour in skill and knowledge, and turn out a superior pilot instantly. It can't be done! It requires some effort on the part of the student.

The other type is the lazy copilot, either getting the ATR or upgrading to captain. In some instances, it may even be a captain upgrading to a new piece of equipment. This is the worst type (especially if also unprepared for flight training), who really screams bloody murder when doing a poor job. However, an instructor may be prepared for the worst if time is taken to review the previous flight training records. Most flight instructors, including myself, very rarely look into the old records unless the student is below average and not making normal progress about midway through training. Then the story is an open book. This type has had trouble in every airplane ever checked out in so there's little reason to believe this time will be any different.

All instructors feel a sympathy for this type. It is a regrettable thing, a rut the student has fallen into and a hard one to get out of. It begins with being a lazy copilot, acquiring sloppy flying habits by flying in the "golden chair" with no responsibility. This type hasn't exercised command or judgment or had to make a decision—including what time to eat the crew meal—in years. For a number of years and several thousand flight hours, even when actually flying the airplane, these copilots have leaned heavily on the captain to do all the thinking and planning. They have either lost or never had sufficient ambition and motivation to take advantage of the opportunity to develop their talents under the direction and supervision of the captain. When they progress to the left seat or transfer to new equipment, they are required to think and plan on their own. Fifty percent of the evaluation for grading on the rating ride is based on command ability and judgment. In every training program, they are again brought face-to-face with the fact that they have become below-average pilots. No wonder they scream so loud. But seniority alone does not make a good pilot or captain.

This industry was built by the pilots. The slogan of the Air Line Pilots Association, Schedule with Safety, tells but a small part of the honor and tradition of the airline piloting profession. Those whom we follow built the tradition and bequeathed a noble heritage that the present-day pilot would do well to emulate.

All of us know and have flown with pilots whom we recognize as being masters of the trade. They demand and receive respect by virtue of their skill and ability; they handle emergency situations with a calm assurance; their flight planning and thinking ahead for contingencies are without parallel; they fly the plane as if they were a part of it, and it seems that the controls move but slightly as they maneuver the craft; the instruments seem glued into the proper place and never waver on an instrument approach. They are dedicated, cautious, and love to fly; and flying seems ridiculously easy for them.

I've known and had the good fortune to fly copilot for many such pilots who would freely impart their skill and knowledge to any copilot showing a willingness to learn. They have a carefully guarded secret to their ability, which I finally learned. That is the reason for this book—to pass that secret on to others. You will find it in the material that follows, in the title, and partially here in the introduction.

Most of those pilots were old-timers whose experience covered all the history of commercial aviation—from the era of the barnstormer and air-mail pilot through all the pioneering stages of airline development. These men have long since left the scene. They were replaced by pilots from World War II, whom the old-timers trained. The present age restriction has closed the cockpit to them.

There are many other pilots who also learned the hard way—those who were too young during the barnstorming era and too old for military service and flight training. These were the young men between wars who wanted to fly and needed the necessary experience to get employment during the depression years. They took any job available—flunkied around airports, worked as line boys, did anything at all, preferably around an airport—in exchange for flight time. Now they too, due to the age 60 rule, have left the cockpit.

Airline pilots today are mostly products of the military, with those of the Vietnam era filling the left seat. Even with this background, the overall experience level is dropping. There is also another factor weakening the crew experience level. Since the cockpit force became a three-pilot crew in 1963, the third person has spent too much time as a flight engineer and lost many pilot skills due to lack of practice. The engineer of a ship doesn't learn the skills necessary to meet the qualifications to command or to be first officer of a ship at sea, and neither does the second officer who monitors system operation of a large aircraft practice learn the skills required to fly it and make decisions. I once had, serving as a second officer in a 727, a former Air Force major, squadron commander, instructor, and check airman in Boeing 707 tankers. Some five years later he upgraded to first officer and, when flying copilot for me, was so slow and had such poor instrument scan that I was virtually flying solo. What a waste! If you were to check the reports of air carrier accidents, you would find that too many of them have occurred when the copilot was flying.

All the good old master pilots had one trait in common—motivation. They learned the fundamentals well, recognized the value of *any* flight experience, and stored away their experiences. They progressed with the industry to newer and more sophisticated planes, but they also applied the techniques they had learned in barnstorming and aerobatics from the days of needle, ball, and airspeed. They modified and improvised upon these lessons from the past to adapt to present-day concepts. They knew that any airplane—a J-3 Cub, a Pitcairn Mailwing, or a DC-8—is just a powered wing! Procedures may change, aircraft may become more sophisticated and complex, techniques may vary slightly due to individual flight characteristics of more modem aircraft, but the theory of flight never changes. The three controls used to fly the J-3 and Mailwing—elevator, rudder, and aileron—are still used to fly the DC-8.

They also believed in themselves as pilots. All good pilots know their own ability and take pride in their flying. They have to have self-confidence or they will be unsure of themselves, plagued by doubts, and never become outstanding pilots.

It has been said that pilots who have been in aviation for 10 years, having reached the age of 32, are the type of pilot they will be for the rest of their lives. If excellent, average, or below average at that stage, they will be exactly the same at age 60, if health still permits them to fly. What they learn during this period—the skills of flight proficiency and the habits they develop in their youth and during early stages of their flying careers—will never be changed.

I believe this to be true, and that's another reason I'm writing this. It's too late perhaps to help those who, through their own laziness, have allowed the opportunity to learn and develop proficiency pass them by. But those who are just getting started, new commercial and corporate pilots, and new-hire airline pilots have a great opportunity to make aviation a very rewarding career. If they can learn even one thing—one item of knowledge, technique, or anything at all that will prove useful in pursuing the left seat—then the time I have spent writing this will not have been in vain.

This material is not intended to take the place of any airline's training manual or the procedures set forth in any training program. It is not a book of instruction as such nor a primer on how to fly (though I will describe various maneuvers and their performance in some detail) but is intended as a guide to supplement training material. It is specifically intended for those who already have a commercial license and instrument rating. It should also prove helpful even to the beginner, particularly in basic instrument flight. I hope it will be interesting reading and provide a subject for discussion even among those who may disagree with my rules of thumb, philosophy, and suggestions relating to technique.

There will probably be many who do not agree with all I say. This is as it should be. I don't profess to be an expert or to present myself as being the world's greatest authority on aviation. Far from it! These are merely methods that have proved useful to me (which I have learned from experience and from others) and helpful to my students. I realize full well that there are probably better methods and easier ways, and I'm eager to learn them. Those who can improve any phase of flying and flight instruction have an obligation to pass it on so that others might benefit from it. If the information is made available, I will be among the first to receive it with an open mind and give it a try.

While still in the introduction, I'd like to give the first suggestion I have to those just entering commercial aviation. Never think like a copilot! Don't get trapped in the rut of the lazy copilot, unless of course your intent is to be a career copilot and you have no ambition to ever occupy the left seat. If you are in the industry as a pilot, you'll probably move to the left seat more quickly than you think. The industry, and its demand for pilots, is moving faster than ever before. If you don't aspire to the captain's chair from the beginning, you'd be better off to seek another way to make a living *now*.

But if you ever intend to fly the left seat, take advantage of your on-the-job training: plan each flight; review the weather; select a route and altitude; figure your fuel requirements and time en route; select an alternate; know your route and destination and alternate airports; have your charts available and up to date; solve your problems of runway requirements for takeoff and landing; and work closely with the other members of your crew. In other words, accomplish all the functions just as you would if you were the captain. Be familiar also with the captain's plan for the flight. And always have a plan in mind during the entire flight, since the second-in-command may suddenly become the pilot-in-command if the captain is incapacitated. Don't be caught short and not know what to do.

Work as a teammate with each captain with whom you fly. Compare your plan for the flight (with the captain's permission, since you in no way should ever try to usurp the captain's authority) to the captain's and see which is better. See if the altitude or route you would have selected would have been better. Who is more accurate in figuring time and fuel requirements? Why? Find out what factors the captain may have considered that never occurred to you. Take every advantage to learn from the captain. Compare each captain's methods; retain what seems best to you and file information in your mind that might help you develop your own methods, which may be a combination of many things you have learned from many people.

When it's your leg to fly (and you never "own" a leg but always fly at the captain's pleasure), fly as if you were in command and accept the captain's criticism as being constructive. Express yourself as positively and tactfully as you can, and fly to the best of your ability at all times. Make climbs and descents, approaches and landings, without the use of autopilot as often as possible to develop and maintain your proficiency. Never forget that the captain is actually in command, is responsible for all your actions and mistakes, and will not be bashful about correcting you if you infringe too greatly upon pilot prerogatives and responsibility.

Be your own greatest critic. Accept each flight as a challenge. There is great satisfaction to be found in flying a trip—planning the flight, flying the weather en route, and finally making a good approach and landing. Work to your maximum ability; endeavor at all times to fly clearances exactly; stay right on your heading and course and altitude; try to fly so smoothly that the passengers will never know when you've made a mistake. You will know when you've flown a good flight, and your self-satisfaction will surpass any compliment that may be given you.

Update for the Fourth Edition

By Billy Walker

The late Captain Jim Webb, Eastern Airlines, authored the first edition of *Fly the Wing* in 1971. The second edition was published in 1990. Captain Webb felt that flying an airplane could be considered a form of human expression. The first two editions of his book dealt with a pilot's skill in planning and executing a flight safely. Webb went into the basics of what a pilot needs to learn fundamentally and then described how to implement this knowledge.

The second edition was published to incorporate changes that had taken place in the industry. That edition reflected the increased use of simulators in both training and checks, which allows more comprehensive training with increased safety and at a reduced cost. Capt. Webb incorporated the latest on the significant changes in ground school (such as greater use of cockpit trainers and improved mechanical and visual aids for pilots), flight training, and check and rating rides, and he added all-new chapters on flying in thunderstorms and low-level wind shear. In the second edition, Capt. Webb included the following note that still holds true: "The aircraft I use as examples (such as the Convair 440, Lockheed Electra, Sabreliner, and DC-9), though some are out-of-date and obsolete (however, many are still flying), are typical of aircraft types. The Convair 440, for example, you may consider typical of a multiengine propeller-driven aircraft; the Electra, of a turbo-prop of any type; the DC-9, of any jet T-category aircraft; and the Sabreliner, of any small jet. Simply use the performance data of the aircraft you are flying or using for training and apply the techniques, rules of thumb, and procedures herein. You will find they work right on the money."

The third edition published in 2004, and now this fourth edition, are extensions of the first two books to bring the aspiring aviator up to speed with state-of-the-art technology, aircraft, and procedures. I updated the text using modern aircraft examples. Where replacing figures and tables was not practical, the online Reader Resources for this book includes additional references, such as the *Honeywell Pegasus Flight Systems Pilot Management Guide*, to assist the reader in improving his/her knowledge base for future safe flying. The Honeywell Guide was developed for the A330/340 but is the program used in the A-318/319/320/321 family, as well.

It is important to note that the online Reader Resources are FOR REFERENCE ONLY. These resources have dated material that is constantly being revised. Therefore, they CANNOT be used operationally.

Captain Webb tells readers to apply the principles and the techniques described herein, no matter which aircraft is being used, and the results will be "right on the money."

Someone once said a teacher can never know how far his/her influence extends. Jim Webb's influence surpasses most. Although Captain Webb has flown west, the knowledge he continues to pass along will be of tremendous value to fledgling professional pilots as they develop their skills and amass the knowledge necessary to survive a hostile aviation environment.

I am proud to have been asked to update Jim Webb's book. However, very little of my input was needed. Some chapters were left largely as is. Some, where it was not practical to rewrite just for the new graphic material, have a summary note referring to the online reader resources.

It has been a great privilege to honor Captain James Webb's memory with the fourth edition of *Fly the Wing*. If this work influences you in a positive way, I believe Captain Webb will smile down on us both!

Blue skies and tailwinds....

1

Ground School and Study Habits

The "new-hire" pilot's first exposure to ground school with an airline will begin with several days of learning company procedures. Ground instructors will guide students patiently through the multitudinous intricacies of the Flight Operations Manual, the various forms to be used as an operating crewmember (the pay form is considered by most captains as being the first officer's greatest responsibility), and the various subjects required by the Federal Aviation Administration (FAA) for pilot indoctrination and recurrent training. These will include jet upset, high-altitude meteorology, takeoff and landing minimums, weight and balance, takeoff and landing data cards, company operations specifications, etc. These subjects are fairly standard for every airline. Some I consider the province of the ground instructor, and I have omitted those from this book. But the others, related more directly to actual flight, we'll get into a bit later. I know of no pilot who has not successfully completed this portion of training.

After completing indoctrination, the new hire will be assigned a category in specific equipment and given a base assignment. Insofar as possible, this assignment will be in accordance with the pilot's stated preference, but the actual assignment will be predicted on the airline's need at the moment. If, for example, the most pressing need at the time is for Boeing 757 first officers in New York—first officers in 757 equipment—the new hire will enter first-officer training for the Boeing 757 and be based in New York upon completion of training. Future assignments and training will be on a bid basis of stated preference and seniority. With an equipment assignment, the trainee will begin the type of ground school training to be repeated many times as progress is made (rewarded by higher pay) to higher-paying equipment and categories demanding more skill and training in specific types of aircraft.

Ground Instructors

The ground instructors will be highly trained educators with a wide diversity of backgrounds. Some will be maintenance specialists with years of experience on the particular aircraft; others will be retired military or airline pilots with thousands of hours of flight experience. They will teach the mechanics as well as the operation of the many systems of the complex transport aircraft. They will also recommend the trainee for the verbal examination, which is given by the FAA for type ratings and certificates and/or by a check pilot for first officers.

It is vitally important that the pilot know the aircraft and its systems thoroughly. Therefore, every modern educational aid is used. The airlines have millions of dollars invested in training aids—films, slides, videos, system mock-ups (electronic boards duplicating various systems), and very realistic cockpit procedure trainers. Additionally, the new generation of teaching aids includes computers. Computer-based training (CBT) is becoming the normal method of teaching aircraft systems. Some airlines do not use stand-up instructors these days.

Every new and proven technique and aid to education is used to make sure that the pilot learns everything needed. It is desirable for the class size to be restricted to eight during the first week, which is spent with the airplane manual and visual aids; then there should be one instructor for two students during the operational study system operation using the mock-ups and cockpit trainer.

When this book was first published in 1971, there was little tolerance for failure at this stage of training—70 percent was no longer a passing grade. The written examinations given at intervals throughout the course and a final exam upon completion required a minimum grade of 85 percent. These standards will hopefully remain the same. That sounds tough! But actually, the class average is usually in the high 90s, and a minimum grade is rare.

After completing the classroom work, the ground instructor takes two students at a time into the cockpit procedural trainer, in most cases a full-sized cockpit environment capable of simulating and accurately displaying system operation and having some limited flight capability. It is, in fact, a flight simulator without full flight capability. It is here that normal, abnormal, and emergency procedures are taught, with the student in the normal operating position. Each procedure, beginning with cockpit preflight, may be drilled until recognition of desired responses as well as malfunction becomes second nature.

The ground instructor also teaches aircraft performance, usually along with cockpit procedures. Pay close attention and spend some time on your own review of the performance charts for your aircraft. They will probably have sample problems drawn on them, but you should actually work a few examples yourself. Use different values from the sample problem and work out at least one (preferably more) problem on each chart. I would suggest that you actually draw it in and make some notes on the margin of the page. This may prove helpful later when you take your verbal exam.

The state of the art of ground school training has reached the point where the student takes the verbal exam upon the completion of ground school and should be well prepared to pass it easily. This allows the flight instructor to dwell more upon system operation and flight maneuvers in the simulator. Actual flight training in the aircraft has been drastically reduced because of the operating cost. The enhanced safety allows more depth of actual practice in critical operations that would be extremely hazardous in the aircraft, and the student (who already knows how to fly) learns far more from hands-on, in-flight practice. The simulators of today are far more realistic, perform with precise results, may be frozen in any stage of flight to thoroughly discuss a maneuver or procedure, and create an uncanny illusion of actual flight. The flight instructor, to turn out students as well-qualified pilots, now has more time to go even deeper into systems and flight techniques than ever before and has time to evaluate students, observe their progress, and cover each system in even greater detail. The instructor can quickly spot a weakness in a particular system, procedure, or flight technique and then has time to concentrate on what the student needs most.

Aircraft Systems

It seems that every individual has a weakness in some particular system that causes the most trouble, even after completing ground school and passing the verbal exam. It is variable but normal. Usually the problem lies in not knowing how to study aircraft systems. I've tried many instructional methods, with varying degrees of success, and have evolved a method of studying an aircraft that is both simple and effective.

Many pilots, particularly those with little or no experience in large aircraft, become bogged down in the many systems and their complexities. They store away in their minds a huge hodgepodge of information about a particular system and then have difficulty relating that knowledge to actual system operation. They try to memorize the manner in which the system is constructed rather than to understand system operation. While it is true that there are some minimum and maximum numbers relating to quantities, pressures, and temperatures that must be memorized, everything else about a system should be considered from a strictly operational standpoint. When learning these numbers, therefore, learn also where they are sensed and where they came from.

There is also a commonality of systems. A hydraulic system, for example, is a hydraulic system. Its construction and operation may vary from airplane to airplane, but many of its features are common to all hydraulic systems. However, many experienced pilots, who have been to several ground schools and studied other comparable systems, seem to have difficulty in learning the same systems in a new aircraft. There is an easy way to learn those systems. Consider what you will need to know to safely fly the airplane and pass your verbal exam and flight check. You will need to know limitations verbatim; normal, abnormal, and emergency operating procedures; systems operation, both normal and abnormal; and emergency equipment location. Let's take these one at a time and discuss how to study them, though not in the order indicated. Let's take the pure reading and memory work first.

Limitations need to be memorized and may be broken down into four sections: (1) weights and speeds, (2) pressures and temperature, (3) operational limitations, and (4) equipment operational limits. By breaking limitations down into these categories, you may take a whole limitations section, reduce it to two pages of notes, and memorize it easily. Emergency equipment location is most easily learned in a similar manner. Most aircraft manuals give you a sketch of the floor plan of the aircraft, showing the emergency equipment location. Newer aircraft have placards showing both what the emergency equipment is and where it is located. Break these down into groups of equipment according to type rather than trying to learn the locations of various equipment from front to rear. The emergency equipment required in transport aircraft is the same in all of them. The only variation is in the number required and the location. For example, you might make a list of the type of (1) fire extinguishers (both water and chemical agent) and location; (2) cockpit emergency equipment; (3) oxygen bottles (both ship's system and walk-around); (4) number and location of emergency exits; (5) life rafts and evacuation slides; (6) escape ropes or tapes; (7) first aid kits; (8) spare and supplemental oxygen masks; and (9) floor access to lower compartments. It's much easier to learn the equipment by classification, number, and location than it is from a chart.

Let me suggest at this point that you will need to do your homework by manual review and study to prepare for the next day's ground school subjects. I also suggest that you use the training aids available, including the cockpit procedural trainer, after classroom hours to increase your knowledge and proficiency. You will need some recreation and adequate rest, but also set aside some study time.

Remember, no two students learn at the same rate or absorb material utilizing the same study habits. Decide what works best for you and build a schedule accordingly.

Next, look at the various systems. You'll need to know them to fly the airplane and perform the operating procedures. Your study of the manual and ground school knowledge can best be used by trying to understand the operation of the system by how it is put together. It is apparent that certain items of quantity (pressures and temperatures, revolutions per minute, voltage and frequency, etc.) must be learned. These are usually maximum and minimum values, which you may have encountered in limitations, but you should also learn the normal values.

Now take every system diagram in your aircraft manual (or the system sketches you may have been furnished in ground school) and the pictures of the system control in your manual. Take every control in the system and visualize in the system diagram just what happens as you operate that control. Trace out the action for each control and learn where to look for positive reaction, i.e., the indication that the control worked. Train yourself to make looking for this response become second nature. Practice this technique and procedure in the cockpit procedural trainer, the simulator, and the airplane. *It's a good habit that may prevent an accident.*

Using system diagrams, locate all pressure and temperature sensing locations. Relate them to the system limitations and indications of abnormal functions. Try to visualize what is going on within the system that may be associated with the warning and caution lights of the annunciator panel.

Take each item of the normal checklist and see what it is doing and how it is indicated in system operation until you know what is going on in any system during any phase of flight or operation and with any system-control use. You want to know what happens when you activate a control and where to look to verify that the desired action took place. I'll guarantee that if you have spent a few hours on your own with this type of study of a system, coupled with what you have learned in ground school and cockpit procedure trainer use, you will know the system. Then you are ready to turn the checklist over and get into abnormal and emergency operating procedures.

Emergency Procedures

Abnormal procedures are not meant to be memorized verbatim. They are related to situations or occurrences considered less hazardous than emergency procedures and are usually handled by use of the flight manual (some operators provide a book of color-coded systems) as a work list. Each flight crewmember, however, is expected to have close familiarity with actions to be taken when abnormalities occur. Some abnormalities, however, do not afford the time to consult the flight manual for corrective action. The items that must be memorized are usually marked by hash-mark enclosures preceding them in the outline of procedures in the abnormal section of the flight manual. In these cases, each crewmember should be able to first perform the appropriate corrective action and then consult the manual to confirm it.

Upon observing an abnormal condition, any crewmember should bring it to the captain's attention and/or the attention of the full crew. At that point the captain must become a "crew manager," delegating responsibilities, calmly seeing that all required procedures are carried out, and seeking the input of other crewmembers based on their knowledge and experience, especially if the situation is or becomes more abnormal than expected.

It is strongly recommended that the captain, upon being advised that an abnormal condition exists, consider the aircraft's altitude, speed, and configuration. If airborne, a safe speed and altitude should be maintained or achieved before beginning corrective action. The captain may delegate the actual flying of the aircraft to the first officer, specifying the altitude, speed, heading(s), or profile to be flown. Emphasis is on someone flying the aircraft, handling radio communications and navigation, and not being too deeply involved in the problem.

The wise pilot will read through the abnormal procedures and will commit to memory those that require action before using the manual as a work list, just as if they were emergency procedures.

Emergency operating procedures break down into two parts: (1) immediate action items (these you must memorize) and (2) clean-up items that may be done from the checklist after the immediate action is completed. The immediate action items are just that—those that require immediate action to cope with the emergency situation. The less important clean-up items are not to be done from memory and may be left to be handled later after the immediate action has taken care of the emergency. But don't try to handle the memory items too fast. Immediate means *first* items and is not to imply great speed. Being too fast often leads to mistakes that could be serious, like shutting down the wrong engine.

Several things are classified as emergency procedures: engine failure, fire, or separation; electrical fire; loss of pressurization; etc. Do not let the term "emergency procedure" scare you. An emergency is only an unforeseen condition requiring immediate action. When such an event occurs, even under adverse conditions, you will still be in control of the airplane and the proper corrective action will handle the situation. Learn the immediate action items of your checklist for such conditions and perform them by command and with deliberation. As you go over the checklist, learn what happens—the whys and wherefores of every step in the procedure. This will allow you to understand what you are doing, remember the procedures more easily, and have more confidence in yourself and your equipment to handle these emergencies.

In general, the correct manner to handle emergencies is as follows: Aural warnings should be silenced as soon as the crew recognizes the emergency; then, when the emergency is recognized, the proper corrective actions should be accomplished.

The captain's primary responsibility is the safety of the aircraft, crew, and passengers. At low altitudes, the captain may elect to fly the aircraft and may give commands such as "Fight the fire!" or whatever. On takeoff with an engine failure and/or fire, I recommend "Silence the bell!" and continuing to fly the aircraft with no further action until in stabilized flight and at the point when minimum obstruction altitude has been reached. Then, step by step, the pilot flying should call out the "immediate" action items, pausing between commands until they are in fact accomplished and verified.

At a safer altitude, if you are the captain and if the particular procedure will not cause you to be the only one left with flight instrument and communication and navigation capability, I recommend that you consider delegating the flying of the aircraft to the first officer so that you may supervise completion of the appropriate corrective actions. It is then the second officer's responsibility, with a crew of three, to read the checklist or abnormal procedure aloud, including the response as the controls are placed in the appropriate position. With a crew of two, the pilot *not* flying and accomplishing the procedure should call out the items and responses as they are accomplished.

The procedures outlined for the more serious and quickly developing emergencies are divided into "immediate action items" and "secondary action items." It is expected that *all* crewmembers will commit to memory the *entire* immediate action items of the checklist. Secondary action items should be accomplished as soon after completion of immediate action items as is practicable under the circumstances, using the checklist as a work list, since it is not expected that crewmembers memorize these items.

Let me illustrate how you might handle an engine fire in a Boeing 727-225. I want to emphasize the importance of knowing what happens step by step in the immediate action items and to stress the deliberate method of executing them. Believe me, this will not be easy. The following is a quote from the original author, Captain Jim Webb. "I used my methods in my own study and have a clear memory of every aircraft I've flown." This is his description of handling an emergency in the Boeing 727. I flew Boeing 737s for many years and remember the procedure being very similar, albeit with a two-person cockpit.

> In the center and above the instrument panel just under the glareshield is the fire protection panel. In the center of the panel are three engine-fire switches; beneath them and guarded when the fire switches are in are extinguisher discharge buttons; between the number 1 and 2 fire switches is the bottle transfer switch; between the number 2 and 3 fire switches and to the lower left of the number 1 fire switch are the bottle discharge lights; above the lower left bottle discharge light is the wheel well warning light; to the right of the number 3 fire switch is the fire test switch, to the right of it the bell cutout button, and to its right the detector test button. The engine-fire switches

are powered by the essential AC bus, all other switches are powered by the battery transfer bus.

Now we have a fire warning, the fire bell alarm goes off, and engine-fire switch number 1 shows a red light indicating a high-temperature condition (fire) in the related engine area. I immediately call out "silence the bell!" to the first officer, who then pushes the bell cutout button. In this quieter environment I call out, "Essential power," to the second officer[1] who verifies that the essential power selector is not positioned to the engine on fire by replying, "Operating generator." I either close or command the number 1 throttle to idle and it is verified verbally. This drastically reduces the fuel flow to the engine, and I will pause for a second to see if the fire warning goes out or is still present. If it is still present, my next command is "Start lever," and the first officer places it to cutoff and verifies verbally; this shuts off fuel to the engine at the fuel control unit. If the fire persists, the next command is, "Engine-fire switch," and the first officer deliberately pulls number 1 and verifies, "Pulled." When this action is taken, the following occurs: engine-fuel shutoff valve, closed; engine fire extinguisher button, armed; generator field relay, tripped after a 5- to 10-second delay; hydraulic supply shutoff valves (number 1 and 2 engines only), closed; and hydraulic low-pressure light circuits disarmed on 1 and 2. Next, "Bottle discharge switch," response, "Pushed," held 2 seconds. The last immediate action item is, "Bottle discharge light," and the response is, "On," verifying that the bottle has fired.

The throttle, start lever, engine-fire switch, and bottle discharge switch actions may cause the fire indication to go away and the warning light to extinguish in the fire switch. When the fire indication no longer exists, I recommend (though it's not on the checklist) that the detector test button be pushed. This performs a continuity test of the firewall, engine, wheel well fire detectors, and the detector circuit ground lights. If it tests normally, you can be reasonably certain that the fire no longer exists. If not?...

That little exercise was for the purpose of showing you, by example, the type of knowledge you should acquire about every system and procedure.

1 Within this chapter some reference is made to procedures which include a Flight Engineer or Second Officer. Virtually all airlines now use only a two-person flight deck crew. Therefore, the procedures while essentially the same now only involve the Captain and First Officer.

Apply the same philosophy to all the operating items on the checklist. Use the system diagrams to trace what is going on as you run through the checklist and accomplish the items. Check pressure and temperature sensing, control and actuating power, action in the system, and the indications with each control function. You'll begin to see the reason for the sequence in the checklist and it will be impressed more firmly in your mind.

The more modern aircraft operated today utilize computers and either cathode ray tube or liquid crystal displays to indicate what is going on both normally and non-normally. It is therefore easy to recognize a problem and follow the prescribed steps to correct whatever went awry. Many new aircraft interface aural signals with the visual information.

That's it. That's the way to learn systems on the airplane as well as the philosophy of coping with abnormal and emergency procedures. This is the easiest method I've ever found, and I know from experience that it works. It takes a bit of homework, but it's worth it. I would also point out that in electrical fire procedures, loss of all generators, and in some electrical system problems, the captain will be the only pilot with flight instrument and navigation and communication capability. Captain Webb's recommendation is for the captain to fly the airplane in the presence of *all* electrical problems. My recommendation is for the captain to instruct the first officer to fly the airplane in most emergencies. Obviously, this is not always practical, but this procedure allows the captain to supervise all aspects of the emergency and always leaves him/her the option of regaining actual control.

As rules of thumb, teach your eyes to look for actuation in the proper place every time you move a control, learn what happens in the system as you move the control, learn where pressures and temperatures are taken, learn control and actuating power for each control, and remember that something that can be turned on can also be turned off. Check operation when turning something off just as you do when turning it on.

Summary

There are several subjects you will study in ground school "jet indoctrination" that relate to flying and jet operation and that must be well understood. I think they are worth going into (in the next three chapters) from a pilot's and an instructor's viewpoint. They can be confusing to some students in ground school, highly technical, and more on an engineering level than a pilot's operational level, so I have tried to reduce them to a more operational form. I'm omitting one subject, high-altitude meteorology, because it is so complicated and wide in scope that it would take another book to cover it adequately. However, I would recommend that a pilot who intends to fly in the jet levels learn something of the weather phenomena peculiar to the upper atmosphere.

Just one further suggestion before we move on. Some of the best students I've had and some of the most senior and best-qualified pilots I know have reduced their notes to a card file. They make notes about the aircraft systems, maneuver profiles, procedures, etc., on 3-by-5-inch index cards and use them for a refresher. One side of the card will pose a question about a system or procedure, and the other side will give the answer. The students carry these cards around with them and use them in spare moments to refresh and retain their knowledge. This system seems to be particularly effective for people who learn best by writing and making notes.

I've also noticed that the best pilots carry different sections of the aircraft manuals with them on every trip and spend at least an hour on layover in study of the airplane. They are conscientious to the degree that they could pass an oral or instrument and/or proficiency check on any given day without any prior preparation or study of any sort. I'd say they have a highly professional approach and attitude.

Use of tablets, so prevalent these days, can be a tremendous asset. They will allow for the use of several different study guides for the particular aircraft to which you are assigned. You can take copious notes and store them for quick referral. Laptops further provide better graphic or pictorial displays of the aircraft systems and operation.

Note

Captain Webb's final word is the key: ATTITUDE! Attitude is an eight-letter word.… With the right attitude you can accomplish your goals more effectively. Since Captain Webb first wrote Fly the Wing, many changes have taken place in our industry. With many technological changes, one thing remains constant.

The right attitude is still one of the most important ingredients to a safe and efficient aviation career.

For example, a growing number of airlines issue a high-tech laptop computer, tablet device, or Electronic Flight Bag (EFB) to the new pilots near the beginning of their training. These computers contain the company manuals, performance program, email, internet, and even study guides. Pilots carrying around heavy flight bags full of manuals will soon go the way of the horse and buggy.

The airplanes are a technological wonder now. As the B-727 did to the earlier piston aircraft, the A-320 through A-380 and the B-777, for example, have made the B-727 obsolete.

2

Basic Aerodynamics

To really fly an airplane, to be a really good pilot, and to utilize the theory of "fly the wing" and the instrument scan techniques necessary in instrument flight, a pilot must of necessity have some understanding of the principles and natural laws involved in the phenomenon of flight—basic aerodynamics. This is not an engineering type of knowledge or deeply scientific but an operational type of understanding about how and why the airplane flies and what the pilot is doing to vary these aerodynamic forces acting upon the craft in flight.

Aerodynamic Forces

Since I mentioned the forces acting upon the aircraft in flight, we may as well dispose of them right now. Most pilots will tell you that they fully understand aerodynamics, that they learned this in ground school before first solo and see no reason to review aerodynamics any further. They will tell you that they know the forces acting upon an aircraft in flight—gravity, lift, thrust, and drag—and know the theory of Newton's laws of motion and Bernoulli's theory of venturis. They may be able to state that the greater the pressure, the slower the speed; and the greater the speed, the less the pressure. They go on to say that a body continues in its state of rest or of uniform motion in a straight line except as it is compelled by force to change that state; that a change of motion takes place in the direction of the straight line in which an applied force acts and is directly proportional to the amount of that force; that every action has an equal and contrary reaction; and that an airplane flies as a direct result of these laws of nature. From these laws are derived the four forces acting upon an aircraft in flight—*lift*, which must overcome *gravity*, and *thrust*, which must overcome *drag*.

All of the above is true, and I have no desire to enter into theoretical argument with those for whom this explanation of aerodynamics will suffice, but it never seemed to me to be enough. It doesn't explain or adequately define the forces acting upon an aircraft in flight—aerodynamics. I've never completely bought the theory that aerodynamics boils down to lift overcoming gravity or weight of the aircraft and thrust overcoming drag. I prefer to think of aerodynamics as the science of, or relating to, the effects produced by air in motion—more particularly the *force* produced by air in motion. Since we can't cause the wind to blow or cause the air to be in motion, we cause the airplane to move by applied thrust, and from then on *all* the forces acting upon the plane in flight are controlled variables. And these forces *are* changed, varied to best utilize the desirable features of each as the pilot causes the plane to maneuver, and are directly proportional to speed and relative motion through the air. Lift must overcome more than the weight of the plane if it is to climb and less if it is to descend. Thrust must overcome more than the inherent drag if the plane is to accelerate in speed, and drag must be greater than thrust if speed is to decrease. To really fly the wing, aerodynamics must be considered in a light different from the classic definitions.

The wing—the airfoil or lift surface—is the whole secret of flight. When an airfoil is moved through the air, a stream of air flows under, over, and around it. If the airfoil has been well designed (by the engineers who need all the theoretical knowledge), the flow will be smooth and will conform to the shape of the moving airfoil. If, in addition, the airfoil is set at the proper angle and is made to move fast enough, the airflow will support the weight of it. And since the airfoil or wing is attached to the airplane, it will support the entire weight of the aircraft. This then is the whole story—the nature of the action that enables wings to sustain, to furnish enough lift, and to support heavier-than-air craft in flight.

Airfoils are usually curved surfaces to take advantage of Bernoulli's theory. But if you hold a piece of paper in front of you, you will find that you can cause the paper to rise simply by blowing over the top of it. All you have done is to create a low-pressure area over the paper. The pressure beneath, which is now relatively greater, does the rest. If, in addition, you hold the paper at a slight angle, causing an airstream to strike the bottom of the paper while it is being held at an angle to the wind, the resultant dynamic force will contribute to the force lifting the paper. Consequently—and this must be apparent—the force exerted on a surface held at an angle to the relative airstream around it is a result of the pressure difference created above and below the surface.

The importance of the speed and angle of the lifting surface to flight performance is easily seen by sticking your hand out the window of a speeding automobile. If you hold your hand flat and level, no sensation is felt other than that of the air flowing over, under, and around your hand. If you raise the forward part of your hand, causing it to move through the airstream at an angle, you will immediately encounter a force that tends to lift your hand. You have just induced lift. You may also tilt your hand downward and cause this lift to disappear and your hand to react accordingly. It must be obvious that these forces, which you feel applied to your hand, either increase or decrease as the speed of the car—and therefore the speed of the relative airstream—increases or decreases. And it should be pointed out that the forces exerted on your hand are not due solely to the dynamic pressure of the airstream your hand is encountering. Rather, this lifting force in either direction is a result of the difference of pressure created above and below your hand.

If you will now compare these little analogies to what you are doing when you raise and lower the nose of a plane with the elevators and thereby change the angle of the wing as it moves through the air, you will see at once how lift may be varied by a change in pitch attitude. You can also see the relationship of pitch attitude to speed; you must position the wing at a greater angle at low speeds to create enough lift to sustain flight. The "angle of attack" is the angle of the wing relative to its motion through the surrounding air.

Believe it or not, we've already completely covered almost the entire essence of 20 hours of classroom instruction on aerodynamics—but in a much more operational manner. We've proved, with a piece of paper and our hand, that a flat surface can be made to support weight or create lift by virtue of its forward motion and angle of attack through the air. But many years ago, someone—I think it was Leonardo da Vinci—discovered that a slightly arched or cambered airfoil surface is much more efficient. So most of the wings with which we are familiar—the airfoil shape that gives the most lift with the least drag (at least in flight below the speed of sound)—are those with a rounded nose at the leading edge, a smooth cambered upper surface, and a sharp tail or trailing edge. Figure 2-1 compares this angle of attack and lift versus drag in a relative airflow.

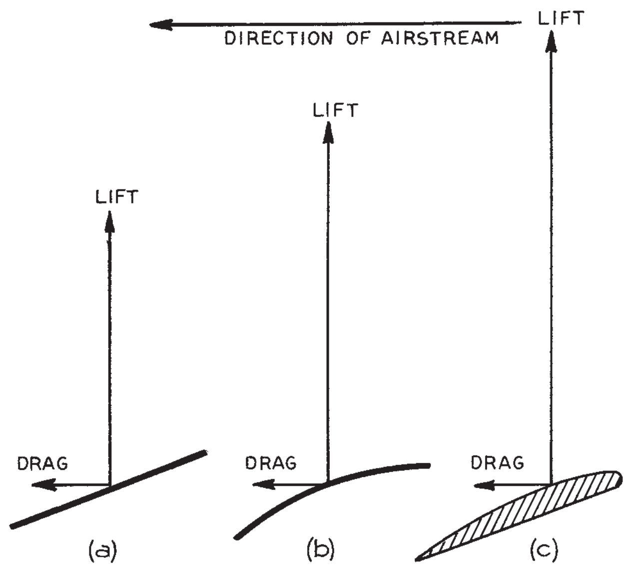

Figure 2-1. Lift vs. drag of various airfoils: (a) flat surface, (b) cambered surface, (c) most efficient shape.

Lift and Drag

The two most important concepts associated with flight are lift and drag. Lift is usually thought of as the force that acts to overcome the weight of the aircraft. But a little thought will prove this statement to be completely inaccurate. The weight of the aircraft is a function of gravity only. But think what happens when gust loads (G loads) or centrifugal forces in steep turns are applied to your airplane. They increase your wing loading, in effect increasing the weight your wing must support. In anything but level flight (normal, constant-altitude flight) the lift is never always exactly equal to the weight of the aircraft. Lift, accurately defined, is always perpendicular to the airfoil and is the force that acts perpendicularly to the drag of the aircraft. This is quite different from comparing lift to gravity when you also consider its relationship to drag. Look again at Figure 2-1; note the angular relationship of lift versus drag, and keep this relationship in mind as we get a little deeper into this subject.

Drag, on the other hand, is the force that acts in opposition to the plane's forward motion. Lift is a desirable quality. Drag is undesirable and must be overcome by lift and *compensated* for by the thrust of the engines.

Now that we've begun to explore some of the mysteries of aerodynamics and talk about lift and drag as if we know what they are, maybe we should more adequately and properly define them. To do so, we must get a bit technical (I don't like to be too technical), but it is not really necessary for you to understand the mathematical formulas. They may appeal to and please some of the more educated minds who read this but are not really essential to fully understand lift and drag.

Lift is the most important. As we have already illustrated, lift depends greatly on the shape of the wing or the form of its airfoil. Lift also depends on the size and position of the wing (angle of attack), the density of the air through which it moves, and the speed with which it moves through the air. The manner in which lift varies with speed may be seen in Figure 2-2.

Lift may be accurately and exactly defined by the relationship:

Lift = $\frac{1}{2}$ p V^2 S C_L; or lift = q S C_L

where p = air density
V = speed of the aircraft
S = plan area of the wing
C_L = lift coefficient
q = $\frac{1}{2}$ p V^2

Diagrams and formulas of this type are usually passed over quickly by most pilots—perhaps from a lack of understanding them—but don't brush over them too quickly. Look at them with a critical and open mind and try to find the message they present. From this illustration and lift equation, you can see that for a given angle of attack, the lift of a wing will vary with the density of the air and the speed of the aircraft. While the angle of attack (α) does not appear in the lift equation, it is there—hidden in C_L, the lift coefficient. The lift coefficient is determined by the design of the wing and varies with the angle of attack. Thus, by changing the angle of attack of a wing—a function of pitch attitude (all other conditions remaining the same)—we vary the lift coefficient in the equation. Consequently, the lift coefficient really gives a true picture of the lifting quality of the wing.

Incidentally, as a result of this, it is customary to define the lifting performance of a wing in terms of lift coefficient and rarely if ever in terms of the actual lift. For aircraft speeds below Mach 0.3, lift coefficient depends only upon angle of attack and can be considered as being completely independent of the velocity. Above Mach 0.3, the speed of the aircraft exerts some influence, but the main factor that controls lift coefficient is still the angle of attack.

This may be seen in Figure 2-3, which depicts the working range of a wing in terms of lift coefficient and angle of attack. Notice that the lift coefficient is zero or less at a negative angle of attack, which you induce by pushing the nose over to descend or dive, and rises in almost a straight line until a certain angle of attack is reached. At this point, the curve usually flattens out and begins to fall, usually steeply.

The straight-line portion of the curve is called the working range of the wing. In this range the wing works well and provides the necessary lift, and the lift varies directly in proportion to the angle of attack. The

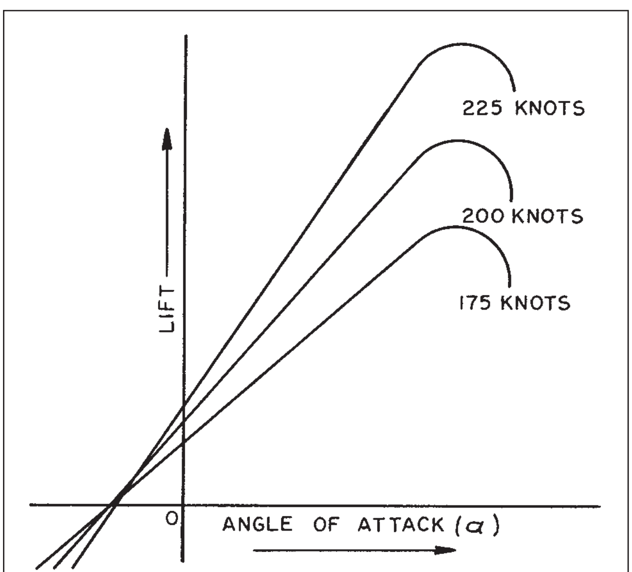

Figure 2-2. Lift increases with speed.

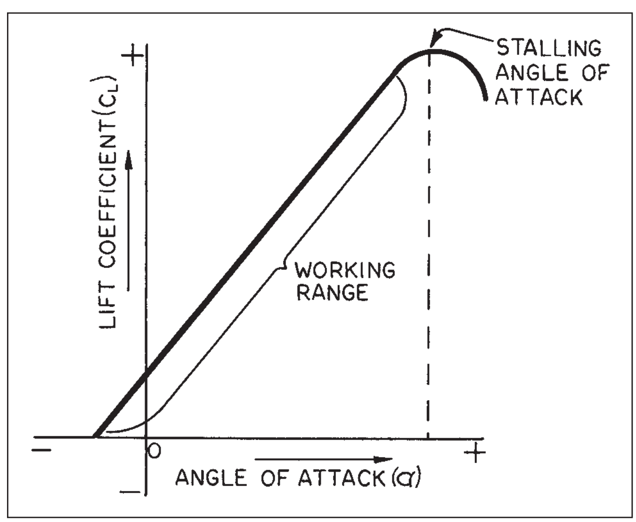

Figure 2-3. Lift coefficient vs. angle of attack

working range of a wing will, of course, vary with design, but a typical wing will have an angle of attack between −3 and +12°. The upper value of the angle of attack (this highest point in the curve) is called the stalling angle of attack. When the angle of attack exceeds this value, the lift begins to decrease and the wing is in a stalled condition.

The aerodynamics of stalls is covered fully in Chapter 12, pertaining to the stall as a required flight maneuver, so it is not gone into here. But an understanding of the relationship of angle of attack to a stall, recognizing that a stall is not solely a function of speed, will make the chapter on stalls more easily understood. Drag also comes into the picture in a stall, and the comments that follow about drag should also be remembered in the performance of flight maneuvers.

Drag is defined by a relationship similar to that for lift:

$$\text{Drag} = \tfrac{1}{2}\, p\, V^2\, S\, C_D$$

where p = air density
V = speed of the aircraft
S = plan area of the wing
C_D = drag coefficient

A plot of drag coefficient versus angle of attack is shown in Figure 2-4.

The numerical value of the drag coefficient of a practical wing is naturally less than that for the lift coefficient in the working range of the wing. This must be true, since the wing must certainly produce more lift than it does drag if the plane is to fly at all. And the variation of the drag coefficient with the angle of attack is quite different, for the drag coefficient values do not follow a straight line. At the stalling angle of attack, the drag coefficient is increasing rapidly. The lift:drag ratio usually reaches a maximum at small angles of attack. After the stalling angle of attack has been reached and passed, the lift:drag ratio falls off very rapidly.

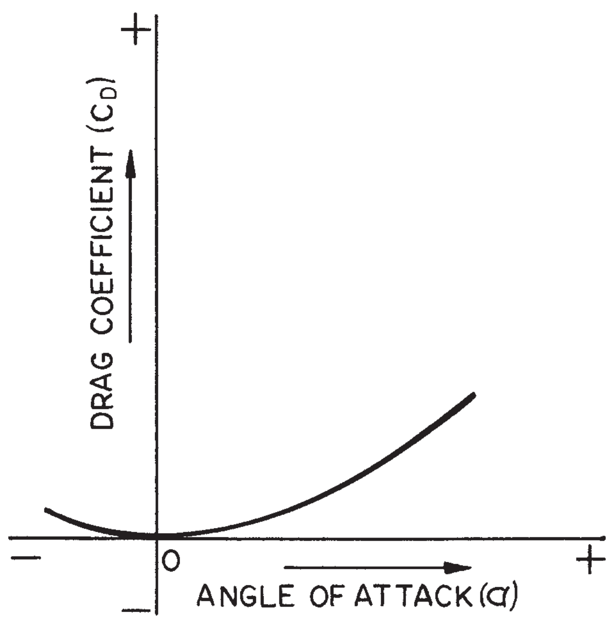

Figure 2-4. Drag coefficient vs. angle of attack.

Air Pressure

Earlier we talked about pressures and pressure differences causing lift. Pressure distribution around an airfoil is the whole key to flight. One condition, and one condition only, must be present for the lifting action of a wing to occur: The air pressure above the wing must be less than the pressure below the wing. This has been determined by experiments connecting manometers to holes made in a test wing at pertinent points and taking pressure readings when the wing is subjected to an airstream in a wind tunnel. Figure 2-5 shows the static pressure distribution readings taken at the middle section of a wing at various angles of attack.

The total lift force exerted on a wing is proportional to the area between the curves of the top and bottom of the wing. That is, the greater the pressure differential, the greater the lifting capability of the wing. As shown in Figure 2-5, the major portion of the lift is caused by the negative pressure on the top side of the wing and occurs near the leading edge of the wing. You can easily imagine that lift will be obtained only as long as the high-pressure airstream below the wing has a solid surface to push against. The sudden appearance of holes in the wing would present the high-pressure air with a convenient shortcut to the upper surface, tending to equalize the pressure differential, and a noticeable decrease in lift would occur. The lower air pressure above the wing of an aircraft in flight results from the fact that the speed of airflow over the top of the wing is greater than the speed of airflow below the wing. This is in accordance with Bernoulli's theorem as applied to airflow: As air increases in velocity it decreases in pressure, and vice versa. If you have always associated high winds with high pressure, this may sound confusing. The thing to remember is that when you stick your hand into a rapidly moving airstream, you feel the pressure, not of the airstream, but of the air that has piled up as the hand stopped its flow. The instant you remove your hand, the air is free to flow again, and the pressure drops as the air "spreads out" and picks up speed. In other words, the pressure you feel is a result of your decreasing the velocity of the moving air by an obstacle.

Billy Walker | **FOURTH EDITION**

FLY THE WING

A Flight Training Handbook
for Transport Category Airplanes

Fly the Wing has been an indispensable comprehensive textbook on operating transport-category airplanes for more than 45 years. Pilots planning a career in aviation will find this book provides important insights not covered in other books. Written in an easy, conversational style, this useful manual progresses from ground school equipment and procedures to simulators and actual flight. Along the way, the author covers the physical, psychological, and technical preparation pilots need in order to acquire an Airline Transport Pilot (ATP) certificate while maintaining the highest standards of performance. *Fly the Wing* serves as a reference to prepare for the ATP FAA Knowledge Exam.

Although not intended to replace training manuals, this book is by itself a course in advanced aviation. With clear explanations and in-depth coverage, it has been described as a "full step beyond the normal training handbook." Pilots who want additional knowledge in the fields of modern flight deck automation, high-speed aerodynamics, high-altitude flying, speed control, takeoffs, and landings in heavy, high-performance aircraft will find it in this resource. This fourth edition of *Fly the Wing* includes access to additional online resources, including a flight terms glossary, printable quick reference handbooks, and numerous supporting graphics.

***William D. "Billy" Walker, Jr.**, began his airline career with the original Frontier Airlines. He joined America West Airlines, where he became the manager of Airbus Flight Training, an FAA APD, and Check Airman. Later, he became part of the start-up team for JetBlue Airways, retiring as the Senior Test Pilot, FAA APD, and Senior Check Airman. Walker is rated in numerous transport types and has flown more than 250 varieties of military and civilian aircraft. He holds FAA ATP and Flight Instructor certificates. Walker was awarded the FAA Wright Brothers Master Pilot Award and was inducted into the Arizona Aviation Hall of Fame.*

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