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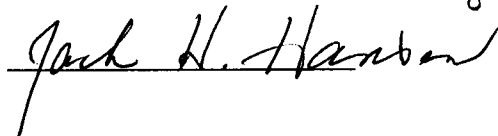
I am submitting herewith a thesis written by William B. Waters Jr. entitled " A Flight Test Evaluation of Seaplane Takeoff Performance with Respect to Delta Ratio." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Aviation Systems.



Dr. William Lewis, Major Professor

We have read the thesis and
recommend its acceptance:





Accepted by the Council:



Associate Vice Chancellor and
Dean of the Graduate School

**A Flight Test Evaluation of Seaplane Takeoff
Performance with Respect to
Delta Ratio**

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

William B. Waters Jr.
May 1998

DEDICATION

To my family,
whose love, support,
and encouragement has
formed the foundation
for all my accomplishments.

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ABSTRACT

Research in seaplane takeoff performance is rare, due to the limited number of seaplanes and the difficulty in measuring takeoff distance on the water. This thesis presents an evaluation of a seaplane takeoff performance metric referred to as delta ratio (D_R), a rule of thumb technique for determining whether or not enough distance is available to make a successful departure from an unfamiliar or obstructed body of water regardless of aircraft weight, and examines D_R as a function of technique. Delta ratio is defined, by previous research, as the water-run distance over the total distance to clear a 50-foot obstacle.

(DeRemer, 1988) In order to evaluate the viability of the D_R , flight tests were conducted by the University of Tennessee Space Institute at the Woods Reservoir, Tullahoma, TN during day VMC for 1.8 hours. Numerous takeoffs were performed at weights of 3050 lb. (light) and 3400 lb. (gross) using three takeoff techniques; conventional (baseline), float-lift, and flap-input. A one-way ANOVA was performed, in conjunction with Duncan's New Multiple Range Test for planned comparison, on the resulting distance information to determine the significance of D_R across weight and technique.

It was determined that D_R should not be applied to takeoff maneuvers using the flap-input technique. However, it was found that the D_R is consistent across weight and technique during takeoff maneuvers that employed the conventional or float-lift technique. It was also determined that the flap-input technique was the only technique that proved to significantly reduce the takeoff distance when a seaplane is heavily loaded. The flap-input technique demonstrated no significant benefit when lightly loaded.

Based on the data gathered and the experience gained from this flight test, recommend the flap-input technique not be employed by novice or minimum currency seaplane pilots.

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LIST OF ABBREVIATIONS

A	Amphibian (A185F)
ABS	Absolute Value
AGL	Above Ground Level
AIAA	American Institute of Aeronautics and Astronautics
ANOVA	Analysis of Variance
BHP _c	Calibrated Brake Horsepower
BHP _T	True Brake Horsepower
CG	Center of Gravity
CI	Compass and Inclinator (Range-finder)
D _R	Delta Ratio
EW	Empty Weight
EWCG	Empty Weight Center of Gravity
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulations
FPM	Feet Per Minute
FS	Front Seat Pilot/Passengers
GPS	Global Positioning System
HUD	Heads-Up-Display

LIST OF ABBREVIATIONS (continued)

IO	Fuel Injected, Horizontally Opposed
KIAS	Knots Indicated Airspeed
MAP	Military Assistance Program
MP	Manifold Pressure
NACA	National Advisory Commission of Aeronautics
OAT _I	Indicated Outside Air Temperature
RMS	Root Mean Square
RPM	Revolutions Per Minute
STC	Supplemental Type Certificate
STDEV	Standard Deviation
STOL	Short Takeoff and Landing
THA	Tulahoma Regional Airport
U	Military Utility Aircraft
VMC	Visual Meteorological Conditions
V _G	Getaway Speed (Liftoff)
V _H	Hump Speed
V _S	Stall Speed
V _X	Best Angle-of-Climb Speed
X _m	Mean Value
X _s	Suspect Value

Chapter 1

INTRODUCTION

Background

Much of the research regarding seaplane takeoff performance corresponds with the popularity of the aircraft and its widespread use throughout the '20's, '30's, and '40's. Research information, that while useful, is neither plentiful nor readily accessible to most pilots. Furthermore, the reduced number of seaplanes in commercial and general aviation fleets, coupled with the difficulty in measuring takeoff performance (distance) on the water, leaves many pilots with inadequate information concerning their operation.

A technique, published by the AIAA in 1988 ^(DeRemer, 1988), provides seaplane pilots with the information necessary for the determination of the required takeoff distance.

The delta ratios arrived at by employing this technique do not require the pilot to have precise information regarding waterway length, aircraft weight, or knowledge of the present density altitude. Evidence supporting this technique comes from de Havilland Aircraft of Canada, Ltd. in a remark from a flight manual concerning the takeoff performance of the DHC-2 Beaver seaplane – “Water run is approximately 68% of total distance” required to clear a 50 foot obstacle. However, the technique assumes that the delta ratios remain relatively constant across the broad range of flight conditions capable of being encountered. ^(De Remer, 1990) This thesis examines seaplane takeoff performance in general, evaluates the delta ratio across weight and technique, and recommends

improvements to render more meaningful results from future research in seaplane takeoff performance.

Takeoff Techniques

Unlike their landplane counterparts, seaplanes are operated on a large variety of water surfaces, ranging from glassy to rough. Moved by winds and currents, such surfaces are often surrounded by terrain and obstructions normally not found in the vicinity of an airport. Furthermore, detailed airport information and weather typically provided to the pilot, is normally not available. Additional pilot responsibilities involve the determination of water depth, evaluation of surface conditions, identification of obstacles (rocks, trees, boats, etc.), knowledge of surrounding terrain elevations, and selection of areas of sufficient length to afford the safe operation of the aircraft. ^(Kelly, 1996)

Seaplane takeoffs can be broken into four distinct phases - displacement, hump (ploughing), planning (on step), and liftoff (see Appendix A, Figure A.1.). With full power applied, the object is to rapidly move the aircraft out of the displacement phase, through the spray (damaging to propellers), and on step as rapidly as possible. With the nose attitude stabilized, the pilot reduces backpressure, allowing the stick to move forward until, if trimmed correctly, planning will begin. Some aircraft require forward pressure to move the aircraft over the hump and into a planning position. However, if the nose of the aircraft is allowed to pitch too low, the forebody of the hull will dig in and porpoising will occur. ^(Faure, 1990)

As the speed increases, hydrodynamic pressure will support the weight of the aircraft at the step of the float. The aircraft achieves a nearly level attitude, and begins to plane across the water, minimizing the wetted surface of each float. This is the planning position, and is generally referred to as being on step. Any deviation from this attitude will create additional drag, prolonging the takeoff run. Otherwise, acceleration to rotation is swift and the aircraft may normally be lifted off with gentle backpressure to the stick or yoke. Backpressure is continued until a positive rate of climb is established, at which point the flaps, if required, are raised and the power reduced to the appropriate climb setting. This procedure describes, in general terms, a conventional takeoff applicable to most seaplanes. ^(Faure, 1990)

However, two other techniques have gained popularity, and are commonly employed in instances where shorter takeoff distances are desired. The first involves lifting one float out of the water while planing (Figure 1.1.). Due to the torque effect, spiraling slipstream, and P-factor associated with having a propeller spinning to the right, the right float is usually lifted as soon as the ailerons become effective. The theory behind this maneuver indicates that a near 50% reduction in hydrodynamic drag occurs, allowing the aircraft to accelerate to liftoff more rapidly. Of course, in theory, this technique would prove especially useful under glassy water conditions (see Appendix B, Table B.1.). The slick, glassy water retarding the takeoff in the absence of the lubricating effects of “bubbles” or pockets of air carried under the floats by ripples and waves. ^(Faure, 1990)

The second technique involves the rapid input of additional flap, beyond that normally used for takeoff, combined with a simultaneous aft motion of the stick or yoke in an effort to lift the aircraft off the water early; after which the flaps are returned to the normal takeoff setting while the aircraft is still in ground effect. This maneuver is primarily dependent upon the floatplane being equipped with manual flaps (flap handle w/ detents), such as the Cessna 180/185 or Maule aircraft. Floatplanes equipped with electric flaps often require that attention be diverted inside the cockpit to view a flap indicator at a time when the pilot's attention should remain outside the aircraft. (Faure, 1990)



Figure 1.1. de Havilland DHC-2 Beaver Employing the Float Lift Technique.

Flight Test Program Overview

The flight test program developed for this project consisted of three stages. Stage one involved the recruiting of personnel, the gathering and evaluation of ground instrumentation and recording equipment, and final site selection and preparation. Stage two involved a preparatory flight to identify and confirm the suitability of the selected water runway with the appropriate test aircraft. The final stage consisted of the actual flight test and evaluation of delta ratio as a viable, useful concept.

This thesis describes this project in a flight test report format. The test aircraft and instrumentation are described, and the flight test procedures explained for the evaluation. The test results and conclusions complete the main body of the text.

Chapter 2

INSTRUMENTATION

Introduction

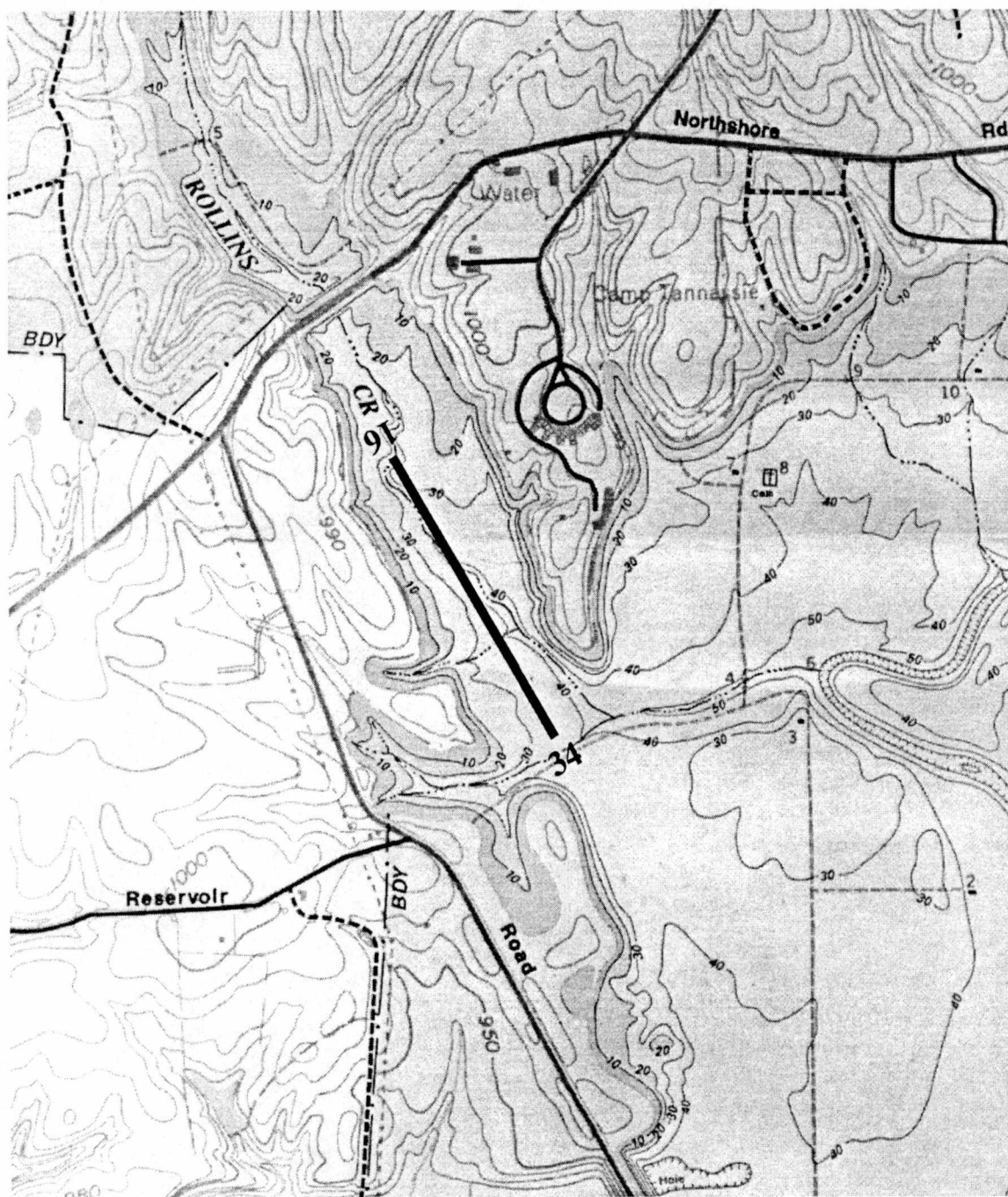
The measurement of takeoff performance (i.e., distance) is difficult and costly information to obtain. There are a wide variety of variables that may be uncontrollable, such as individual pilot technique. In addition, the size of the data collection team, coupled with the amount of equipment required, complicates an already lengthy data collection and reduction process. Perhaps such difficulty is the reason the FAA does not require manufactures to provide takeoff data for aircraft with gross weights of less than 6,000 pounds. (Kimberlin, 1997)

Regulations do exist, however, for aircraft weights in excess of 6,000 pounds gross. Light aircraft, less than 12,500 pounds gross weight, are covered under FAR Part 23. While FAR 25, the transport category, covers aircraft gross weights of 12,500 pounds or more. The primary difference between these regulations lay in the required obstacle clearance height - requirements are 50 feet and 35 feet, respectively for light and transport category aircraft. The latter figure seems odd until you consider the quality of the airports from which these aircraft are designed to operate. Transport aircraft typically operate from facilities featuring clearways - areas beyond the runway that provide additional obstacle-free airspace for climb. (Kimberlin, 1997)

In order to determine the instrumentation required for measuring seaplane takeoff performance, it is necessary to understand the additional problems inherent with operating an aircraft on the water that makes the use of traditional techniques and equipment difficult or impossible to use. For instance, a standing start at brake release is obviously not possible. And, while it may be advantageous to have calm conditions for flight tests, the resulting glassy surface condition produces the greatest amount of hydrodynamic drag. Without the lubricating effect from pockets of air carried under the floats by ripples and waves, the aircraft will be slow to accelerate. ^(Faure, 1990) In addition, the site selected has to provide adequate takeoff distance, yet not so large as to inhibit the employment of the instrumentation from the shore (Figure 2.1.). Of course, more common sources of error like coordination among team members and their skill with the equipment and instrumentation is exaggerated in the less hospitable lakeside environment.

Data Acquisition

In order to gather the requisite data points, two laser rangefinders were evaluated for their ability to provide accurate distance information while tracking the aircraft throughout its takeoff departure path. The first unit, provided by Opti-Logic Corporation, proved incapable of supplying either accurate distance or tracking capability and was immediately eliminated. The second unit, the Essco AdvantageTM CI Laser Rangefinder, provided by Laser Atlanta Optics, Inc. supplied accurate distance information, yet failed to adequately track the aircraft once the takeoff maneuver began. The problem involved



test site.cvs

Figure 2.1. Test Site - Rollins Creek, Woods Reservoir.

an algorithm that did not allow the tracking of dynamic targets (uncooperative) at speeds greater than 15 mph. (Laser Atlanta, 1997)

Equipped with a Indium Gallium Arsenide (InGaAs) laser operating in the near infrared spectrum, the AdvantageTM (Figure 2.2.) is eyesafe and capable of measuring distances up to 2,000 feet without a reflector or 32,000 feet with reflection. The unit also features a magnetic flux compass and inclinometer in order to provide bearing and inclination to the user. Total possible azimuth error is +/- 1° root mean square (RMS) when level, +/- 1.5° RMS when tilted. RMS values from the instrument error curve (sine wave) are smaller than peak by a factor of 1.414. The compass, a three axis magnetometer, reads the stationary magnetic field as baseline while continuously compensating for earth normal (declination + magnetic heading) with each movement of the rangefinder. (Laser Atlanta, 1997)

The AdvantageTM also features a Heads Up Display (HUD) as the aiming mechanism, with range, bearing, and inclination information displayed for review by the operator. The unit is powered by a rechargeable NiCd battery enclosed in the pistol grip, providing five hours of normal use. In addition, the entire unit weights only 4.7 pounds and is GPS and PC compatible via a type II PCMCIA slot or RS-232 port. (Laser Atlanta, 1997) More detailed specifications are given in Appendix C, Figure C.1.

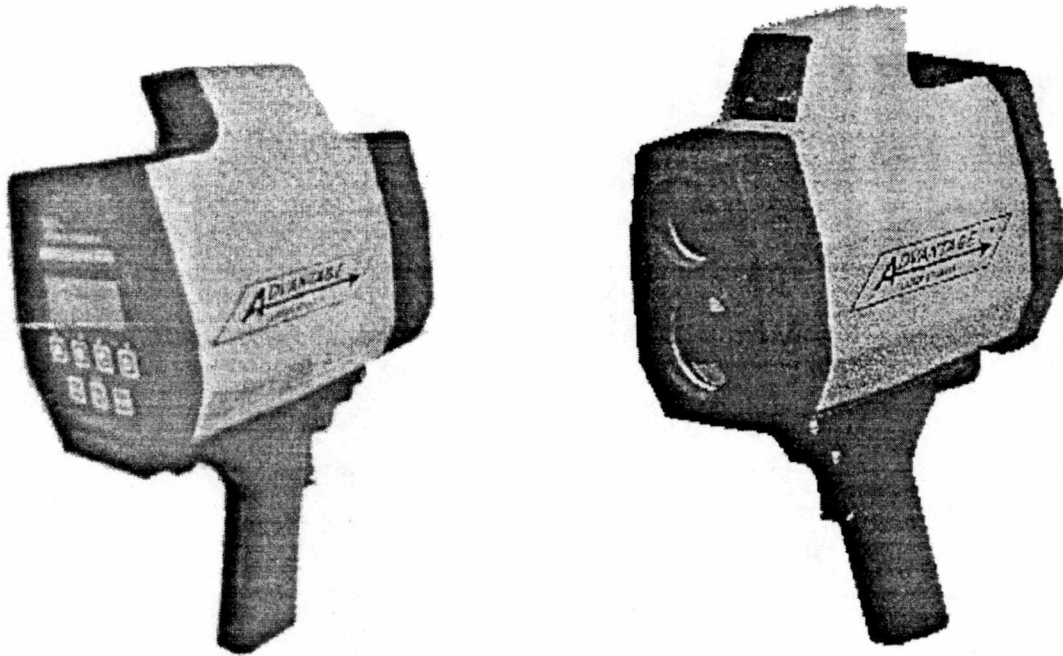


Figure 2.2 Essco Advantage™ Laser Rangefinder.

The 50-foot obstacle height was measured with a device called a sight bar or “harp” (see Appendix D, Figure D.1.). Simple and inexpensive, the sight bar is placed a known distance (500 feet) from the takeoff departure path near the approximate point at which the aircraft achieves its obstacle-clearance height (50 ft.). Obviously, the accuracy of this method is highly dependent upon the observer operating the sight bar. However, unlike a theodolite or strip camera, the raw data is available immediately. This simplifies data gathering and reduction, makes numerous data runs more feasible, and allows the test team to acquire a larger statistical sample. (Kimberlin, 1997)

Pitot-Static System Calibration

Pitot-static systems normally contain three sources of error – position, lag, and instrument. Lag error is significant to flight testing only as measure of the length and diameter of the tubing in the pitot-static system. However, instrument error is present in most mechanical instruments due to their design and assembly. Typically showing up as hysteresis and/or bias error, it is easily accounted for by calibration. (Kimberlin, 1997)

The position error is typically due to the influence of the aircraft’s changing pressure field on the pitot and static pressure ports. Because of its position, the pitot tube remains relatively unaffected by small angle perturbations. Static pressure ports are the main source of error; and their location on the airframe dictates the magnitude of the error between the free stream and system pressure. (Kimberlin, 1997)

In order to produce reliable airspeed data, one of several flight test procedures is commonly conducted to determine the position error. For this flight test program it was deemed unnecessary as the aircraft would be operating primarily in ground effect, representing a significantly different pressure field than that present at altitude. In addition, takeoff performance is a measure of the transition from ground operation to flight. Making this transition as short as possible is the chief consideration in defining the takeoff performance of the aircraft. ^(Smith, 1992) Therefore, having the ability to measure distance, along the takeoff departure path, negated the need for correction and calibration of the airspeed indicator due to instrument or position error.

Chapter 3

AIRCRAFT DESCRIPTION

History

The Cessna 185 Skywagon has roots that date back to 1951 as design work began on its immediate predecessor, the Cessna Model 180. As Cessna's radial engine C190/195 series airplane (Figure 3.1.) began to lose market share to the lower cost Beechcraft Bonanza, it became apparent that Cessna would be required to respond with a new, high performance single-engine aircraft. Even though conventional (tail dragger) landing gear was planned, Cessna made every effort to optimize the 180's cruising speed for its role as a fast, high-altitude personal aircraft, with superior takeoff and landing performance. Moreover, it could be easily converted to floats, skis, or cargo hauling operations. (Thompson,

1992)

In order to provide the Cessna 180 with cruise performance comparable to its heavier, retractable competitor, a 225 HP, horizontally opposed six-cylinder engine, recently developed by Continental Motors Corporation, and a Hartzell constant-speed propeller were selected. Aerodynamically, the aircraft made extensive use of flush rivets on the engine cowl and wing leading edges, while also featuring an adjustable horizontal stabilizer (to minimize trim drag in cruise), cowl flaps, wheel brake fairings, tubular tailwheel spring, and a flush carburetor air inlet. First flown on May 26, 1952, the prototype met or surpassed all of the original design goals. With an original gross weight



Figure 3.1. Cessna 195.

of 2,550 pounds, the C-180 demonstrated a maximum level flight speed of 165 mph, an 1,100-fpm climb rate, and a service ceiling of 19,800 feet. (Thompson, 1992)

Destined to become the world's most popular floatplane, the 180 did exhibit a few adverse characteristics inherent to many seaplanes. For example, the cable system friction of the water rudders inhibited the free return of the air rudder during directional stability tests. To improve the situation, the FAA test pilot permitted Cessna to loosen the water rudder cables and lubricate the pulleys. Later models, 180J/A185F, employed a non-linear spring system in the rudder control circuit to provide ample rudder return. Many floatplanes exhibit a decrease in lateral/directional stability over their landplane counterpart due to the additional cross-sectional area forward and below the aircraft's center of gravity (CG). (Rice, 1979) The other significant change in flight characteristics that occur with the float installation includes a steeper nose-down pitch attitude and increased rotational velocity (inertia effects) during spins. Subsequent improvements to the production of the C-180 include: a change to the 230 HP Continental O-470-K engine in 1956; optional 88 gallon fuel tanks in 1962; adoption of the C-185 fuselage, wings, and landing gear in 1964; standard-T flight instrument grouping in 1967; a 300 pound capacity cargo (belly) pod in 1970; and a camber-lift wing with bonded leading edges in 1973. (Thompson, 1992)

As aircraft equipped with tricycle landing gear began to dominate the personal airplane marketplace of the late 1950's, the Cessna 180 was moved almost entirely into a utilitarian role. This encouraged Cessna to respond with the development of the heavy

hauling 185 Skywagon in 1960. Equipped with a fuel-injected 260 HP Continental IO-520 engine, the C-185 featured a useful load 6.6% higher (1620 lb.) than the aircraft's 1520-pound empty weight. In order to accommodate the additional payload, 32-inches was added to the length of the baggage compartment. The new powerplant also required a larger dorsal fin to prevent rudder lock, in the floatplane, at excessive angles of yaw during directional stability tests. (Thompson, 1992)

Other variants included the 1970 introduction of the A185E AgCarryall, an agricultural spray plane designed for the South American market. More notably, hundreds of customized C-185's were supplied to countries all over the world via the Military Assistance Program (MAP). Deliveries began in 1963 with the U-17A (Figure 3.2.) and ended ten years later with the U-17C. When production ended in 1984, the C-185's gross weight had increased to 3,350 pounds, made possible by the current standard powerplant, a Continental IO-520D capable of producing 285 HP (300 HP for takeoff). In all, 10,634 180/185 series aircraft were manufactured over a 31-year period, the longest production run of any Cessna aircraft. (Thompson, 1992)

Test Aircraft Description

The aircraft used for the flight test was a 1977 Cessna A185F Skywagon (s/n 185-03386), registration number N112SM (Figure 3.3.). Based at the Tullahoma Regional Airport (THA), the aircraft was provided to the University of Tennessee Space Institute (UTSI) by owner/operator Stan McNabb.

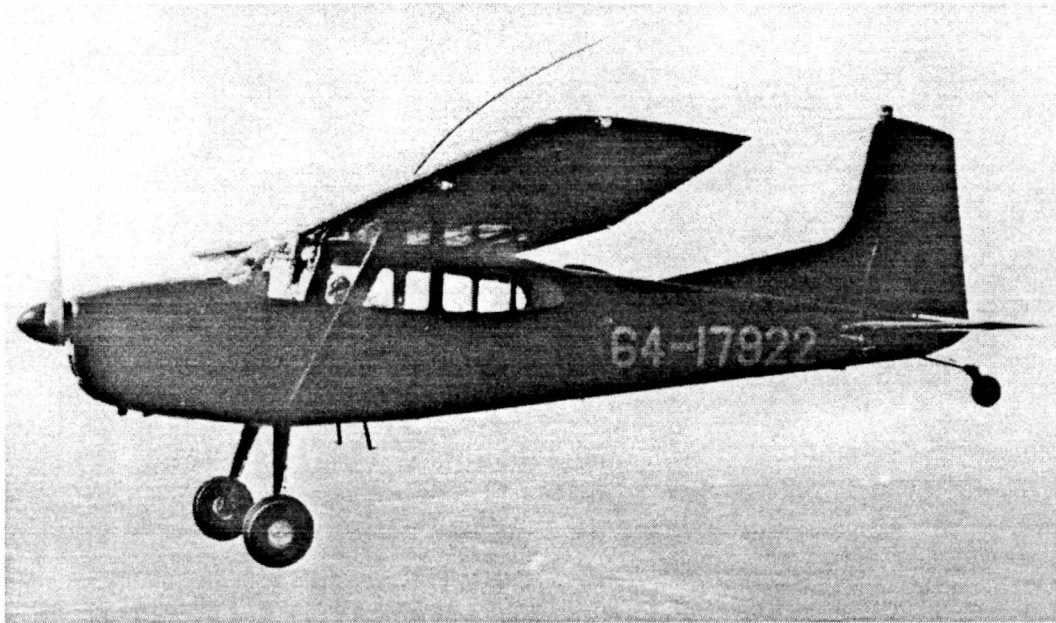


Figure 3.2. Cessna U-17A.



Figure 3.3. Cessna A185F Skywagon - N112SM.

The A185F Skywagon is a multirole, amphibious aircraft used worldwide to haul passengers and cargo in remote regions; e.g., Canada and Alaska. Capable of seating six people, the A185F is more commonly configured for two to four people plus cargo. Normally flown from the left seat, all remaining seats may be removed for the carriage of oversized cargo. Access is through two doors (each with hinged storm windows), one on each side of the aircraft, and a baggage door located on the port side, just aft of the wing. The starboard door has quick release pins in order that it may be removed for loading more cumbersome cargo. Affixed to the aft cabin wall, the fifth and sixth passenger seats may be folded and stored as required. The cabin is contained in a semi-monocoque fuselage made of aluminum alloy and incorporates front and rear carry-through spars to which the wings are attached. ^(Taylor, 1983) In addition, the float installation requires a V-brace, behind the windshield, between the tops of the front door posts and the cowl deck to reduce fuselage torsion on the water. ^(Thompson, 1992) A three-view depiction of the Cessna A185F is provided in Appendix E, Figure E.1.

The A185F wing, which incorporates airfoil section NACA 2412 (modified), is of all aluminum alloy construction, save the fiberglass wing tips, and employs a conventional two spar arrangement. Braced with a single strut on each side, the wing's dihedral is set at $1^{\circ} 44'$, while incidence at the root is $1^{\circ} 30'$, and $-1^{\circ} 30'$ at the tip. Trailing edge control surfaces consist of modified Frise ailerons and, inboard of the ailerons, single-slotted mechanical flaps. ^(Taylor, 1983) The fact that the aircraft is equipped with mechanical flaps, and not electric or hydraulically actuated flaps, is important because they make instantaneous and precise flap modulation possible during takeoff. ^(Thompson, 1992) The

empennage is an all aluminum cantilever configuration, except for the fiberglass end-caps, that makes use of a variable-incidence horizontal stabilizer. Rudder trim is accomplished via a rudder trim bungee. (Taylor, 1983)

Housed in the nose of the aircraft is a 300 HP Continental IO-520D engine; driving a McCauley D3A32C90/82NC-2 three-bladed, 82-inch, constant-speed propeller with spinner. The propeller installation is in place of the original two-bladed 86-inch unit, and made available via Supplemental Type Certificate (STC) SA240NW from Kenmore Air Harbor, Inc. The STC was developed to help owners placate an increasingly noise conscious public and to comply with subsequent noise regulations imposed by the FAA. Cessna, recognizing the problem as well, introduced a three-bladed McCauley propeller in subsequent production models. (Thompson, 1992)

The fuel system consists of two rubberized fuel bladders containing a total of 88 gallons, of which 84 are usable. In order to prevent the fuel-injected engine from sucking air from a dry tank, a fuel accumulator (header) tank is installed in the belly of the forward fuselage. Fuel flows through a remotely located fuel shut-off valve and an optional LEFT – RIGHT – BOTH ON selector valve. The auxiliary fuel pump rocker switch panel consists of HI, LO, and OFF positions on the right side, while the left provides for MAX HI and OFF. The MAX HI position allows for high-powered engine operation with an inoperative engine driven fuel pump. This position is also helpful for purging vapor from heat soaked fuel lines in the engine compartment prior to start up – this is of particular

importance to seaplane operations conducted on rough water and fast flowing rivers.

(Thompson, 1992)

The A185F electrical system is powered by a 28V 60A engine driven alternator and a 24V 33Ah battery. Brakes are hydraulically actuated disc type, while landing gear retraction and extension is accomplished via an electrically driven hydraulic pump.

An engine driven vacuum system provides for the operation of gyro instruments. (Taylor, 1983)

A. Horton STOL Kit Description

High hydrodynamic forces make the addition of short takeoff and landing (STOL) features an attractive option for many seaplane operators. The test aircraft, N112SM, is modified with a STOL kit developed and marketed by Horton STOL Craft, Inc of Wellington, Kansas. The STOL kit (STC SA968CE & SA2286CE) consists of wing leading edge cuffs, drooped wing tips, stall fences, aileron and flap gap seals. These devices are aimed, in theory, at drag reduction and the control or modification of the stall characteristics of the airplane (see Appendix F, Figure F.1 thru F.4.).

B. Float Kit Description

The test aircraft is equipped with PK D3500A amphibious floats (STC 877EA) from DeVore Aviation Corporation of Albuquerque, New Mexico. Of all aluminum alloy construction, with rubber nose bumpers, the floats displace 3420 lb. of water each. FAR Part 23.751 requires reserve buoyancy of 80% - the PK D3500A installation on the A185F maintains 104%. The additional buoyancy enables the A185F to increase it's

waterborne gross weight to 3350 lb., a 250lb. increase over the original Edo 597-2790 amphibious floats. The water rudders, installed on the stern of each float, are designed to provide directional control while the floats are in the displacement mode. Total weight of the amphibious float kit is 725 lb. (see Appendix G, Figures G.1 thru G.4.).

Chapter 4

TEST METHODOLOGY

General

In 1987 the Center for Aerospace Sciences, University of North Dakota conducted research to develop a rule-of-thumb metric (Delta Ratio) for determining seaplane takeoff performance - that is the actual distance of the water run (distance on the water) over the total distance to clear a 50-foot obstacle (total distance from the beginning of the departure to the point where the floats of the aircraft are 50 feet above the surface). In December 1997 a flight test was conducted with a Cessna A185F at the University of Tennessee Space Institute to examine the validity of this metric.

Flight Crew Procedure

Individual pilot technique serves as a significant source of error in the collection of takeoff performance data. Therefore, each takeoff maneuver was made according to simplified, consistent procedures for each of the three techniques to be measured. The procedure was as follows:

1. Idle power in the approach to the start point, departure area clear, water rudders down, 20° of flap set, ground crew ready.
2. Pilot coordinates the application of full power ("ready, ready, now") with the ground crew, full aft stick, rudder as required, water rudders up.

3. Pilot calls “ready, ready, step”, and “ready, ready liftoff” to convey a positive indication of being on condition.
4. Pilot/Observer reads airspeed at step and liftoff.
5. Pilot climbs at best angle of climb speed (V_x) or better and maintains heading (+ or $- 5^\circ$) until the ground crew provides a positive indication of when to read for the 50-foot data point.
6. Pilot/Observer reads airspeed at 50-foot altitude.
7. When employing the float lift technique, the pilot applies full left aileron at 55 KIAS, and rudder as required.
8. When employing the flap input technique, the pilot applies instantaneous aft stick and additional flap ($+10^\circ$) at 55 KIAS. Off the water, additional flap is removed and the aircraft is allowed to climb out of ground effect.

Ground Crew Procedure

The importance of coordinating with the flight crew should not diminish coordination between members of the ground crew (see Figure 4.1.). The procedure was conducted as follows:

1. Pilot applies full power at the start point, timing begins, and the rangefinder tracks the aircraft and the range (bearing) is recorded.
2. Time and range (bearing) is recorded on condition at the pilot's command.



Figure 4.1. Cessna A185F N112SM at Woods Reservoir.

3. Aircraft enters the sight gauge, and the 50-foot mark is called by observation - time and range (bearing) are recorded.

A map depicting crew position and location layout may be found in Appendix H, Figure H.1.

Flight Test

The Cessna A185F selected for this experiment was available for two flights, totaling 2.5 hours, completed by one pilot and one observer. The initial flight, in October, served as a familiarization flight and as an opportunity to gauge the suitability of the selected site.

The second flight took place in December and involved the collection of data during 18 takeoff maneuvers. The relatively small number of takeoffs reflects owner concerns over insurance and limited financial resources. However, it was felt that a carefully controlled, well-executed test would provide sufficient data to evaluate seaplane takeoff performance with respect to delta ratio and technique.

The day the actual flight test was conducted, the aircraft was loaded to an average weight of 3050 lb. (light) for the first set of nine takeoff maneuvers and was manned only by the pilot. The second set of nine takeoff maneuvers were conducted at an average weight of 3400 lb. (heavy) with the addition of an observer and 200 lb. of ballast to the baggage compartment (Cargo C). The weight change, a 10.3% increase, was accompanied by an aft shift in CG of only .53 inches. Table 4.1 contains the weight and balance information for the test aircraft, N112SM.

Table 4.1. Weight & Balance - N112SM

EW Moment - 94881.37

EW - 2485.68

EWCG - 38.17

Pilot - 180 lb.

Co-Pilot/Observer - 205 lb.

Gross Weight - 3350 lb.

Useful Load - 876.32 lb.

Light Weight

	<i>lb.</i>		<i>Moment</i>
<i>EW</i>	2485.68		94881.37
<i>FS</i>	180		9000
<i>Fuel</i>	<u>401.4</u>	(66.9 gal.)	<u>19100</u>
<i>Total</i>	3067.08		122981.37
<i>CG</i>	40.097216		

Gross Weight

	<i>lb.</i>		<i>Moment</i>
<i>EW</i>	2485.68		94881.37
<i>FS</i>	385		14750
<i>Fuel</i>	354	(59 gal.)	17000
Cargo C	<u>200</u>		<u>12500</u>
	3424.68		139131.37
<i>CG</i>	40.626094		

The flight test was performed with light and variable surface conditions, and temperatures of 8° to 14° C. Winds aloft (50-foot) were recorded as 200° to 245° (40° to 85° right crosswind) at speeds of 3 knots or less, and visibility was unrestricted. While these conditions are normally ideal for flight test, the resulting glassy water conditions degrade takeoff performance.^(Faure, 1990) Appendix I, Table I.1 contains a summary of the test conditions from the December flight.

RESULTS AND DISCUSSION

General

The purpose of the flight test was to determine whether a pilot could accurately estimate the required distance for takeoff using the delta ratio (D_R). Data was recorded on 18 takeoffs, three replications of three techniques at two substantially different weights. An analysis of variance (ANOVA) was performed on the distance data, and resulting delta ratios, to determine their degree of significance.

Data Analysis

A. General Calculations

The initial data reduction involved the correction of airspeed information for instrument error and wind correction. The equations for true brakehorsepower (BHP_T) were as follows:

1. OAT_I from Fahrenheit to Celsius; $^{\circ}C = 5/9 (^{\circ}F - 32)$
2. $BHP_T = BHP_c (T_s / OAT_I + 288.16)^2$

Calibrated brakehorsepower (BHP_c) was provided by the Continental Aircraft Engine Operators Manual for the IO-520 Series. Calculated BHP_T revealed only a slight drop in horsepower during the course of the flight test. A plot of airspeed versus time (Figure 5.1) illustrates the significance weight has on prolonging takeoff time.

Cessna A185F Skywagon

N112SM

Configuration: Takeoff (20 deg. flap)

Power: Full Power

16-Dec-97

Pressure Altitude: 720-810 ft.

Gross Weight: 3067.08 to 3424.68 lb.

C.G. Position: 40.10 to 40.62

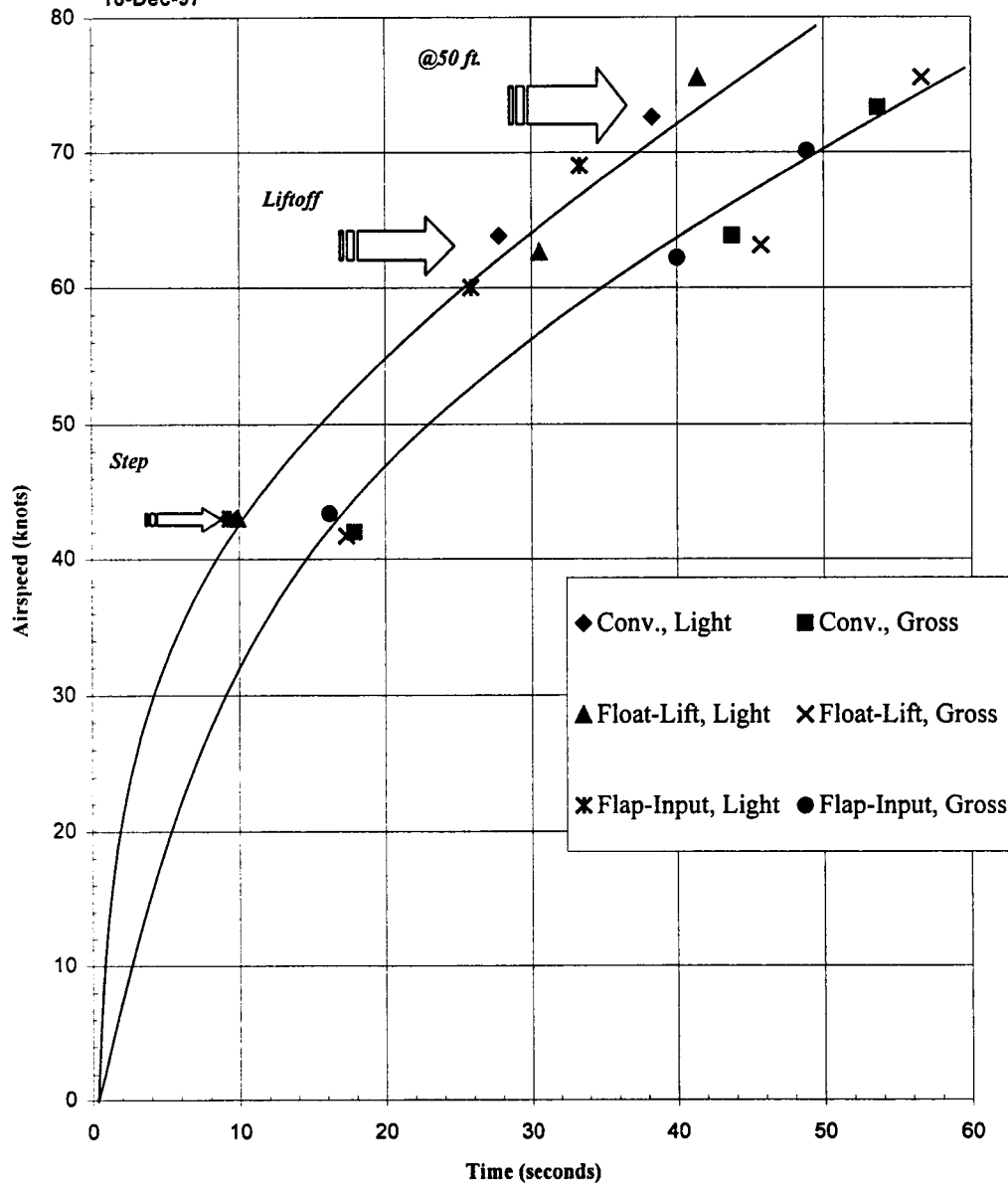


Figure 5.1. Airspeed vs. Time ~
Mean of Three Replications

B. Measured Takeoff Distance

Distance information provided by the laser rangefinder came in the form of bearing information only; the unit proved incapable of providing sufficient, real time, range information on a moving target. Therefore, knowing the position of the starting point relative to the boat, and the departure path of the aircraft, allowed for a simple right triangle solution for converting the bearing information into distance traveled. Total azimuth error of $\pm 1^\circ$ RMS translates into a maximum possible error of 8.7 ft at liftoff and 21.8 ft. at the obstacle-clearance height. An example (takeoff # 10 - conventional technique; heavy) is as follows (see Figure 5.2):

1. Bearing to the start point, 346.4° (2455 feet).
2. Bearing of the departure path, 156° .
3. Bearing and distance from the boat to a point perpendicular (Point P) to the departure path, 63.2° and 435.87 ft. Note this point is also 2374.87 ft. from the start point ($\tan 10.4^\circ = 435.87/X$).
4. Bearing to step occurs at 349.6° , forming an angle of 13.6° with the departure path. The equation, $\tan 13.6 = 435.87/X$, indicates a distance of 1801.86 ft. from step to Point P.
5. Actual liftoff occurs at a bearing of 69.4° , forming an angle of 3.4° south of the perpendicular intercept to the departure path. The equation, $\tan 3.4^\circ = X/435.87$, indicates a distance of 25.9 ft.
6. The aircraft climbs to 50 ft. AGL at a bearing of 139.9° , forming an angle of 16.1° with the departure path. The equation, $\tan 16.1 = 435.87/X$, indicates a distance of 1510.10 ft south of Point P.

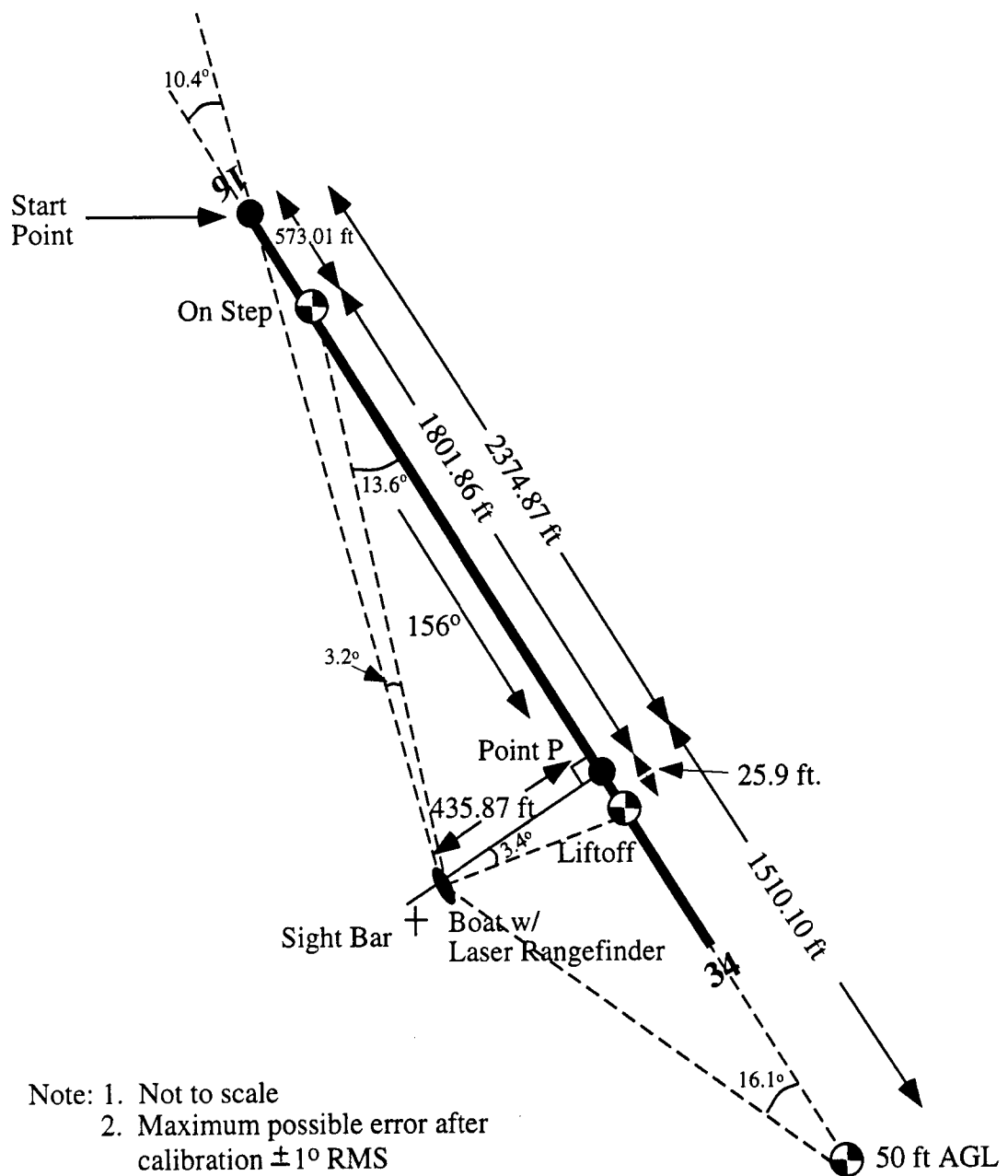


Figure 5.2. Measured takeoff distance (takeoff #10 - conventional, heavy).

7. Thus, the aircraft comes on step at 573.01 ft. (= 2374.87 ft. – 1801.86 ft.); achieves liftoff at 2400.77 ft. (= 2374.87 ft. + 25.9 ft.); and climbs to 50 ft. AGL at 3884.98 ft. (= 2374.87 ft. + 1510.10 ft.).

C. Statistical Significance

Distance information was examined first for the presence of outliers, that is data that appears to substantially deviate from other members of a set. Using the Grubbs test, three data points were eliminated with a 10% risk of false rejection. The Grubbs test is defined as follows:

$$\text{ABS } (X_m - X_s) / \text{STDEV}$$

Where X_m is the mean value; X_s is the suspect value; and STDEV is the standard deviation. Further elimination of suspect data, based purely on experience, was ruled out due to the limited size of the data population (see Appendix J, Table J.1.). Results from this process are provided in Table 5.1.

A one-way ANOVA was performed on the distance information, and subsequent delta ratios, to determine if the null hypothesis could be rejected. The results from the ANOVA were followed with Duncan's New Multiple-Range Test for planned comparison at the 95% level of confidence. (Steel and Torrie, 1980) The equation is as follows:

$$\alpha_p = 1 - (1 - \alpha)^{p-1}$$

Where α_p is the significance level for a subset with p groups at the .05 level of significance. Table 5.2 contains the one-way ANOVA statistics report for all significant items along with the results of Duncan's New Multiple-Range Test.

Table 5.1. Seaplane Takeoff Performance ~ Mean of Three Replications

<u><i>Takeoff Technique</i></u>	<u><i>Light Weight</i></u>	<u><i>Gross Weight</i></u>
<u>Time to Liftoff (seconds)</u>		
Conventional	27.8	43.8
Float Lift	30.6	45.8
Flap Change	25.9	40.1
<u>Time to 50 Feet AGL (seconds)</u>		
Conventional	38.3	53.7
Float Lift	41.5	60.3
Flap Change	33.4	48.9
<u>Distance to Liftoff - Water Run (feet)</u>		
Conventional	1169.2	2375.6
Float Lift	1266.7	2465.3
Flap Change	1101.5	2135.1
<u>Distance to 50 Feet AGL (feet)</u>		
Conventional	1716.6	3233.3
Float Lift	1862.6	3537.3
Flap Change	1815.8	2672.5
<u>Delta Ratio</u>		
Conventional	0.681	0.735
Float Lift	0.68	0.697
Flap Change	0.607	0.799

Table 5.2. Significant Results: One-Way ANOVA Statistics Report

Gross Weight

Water Run Distance: Flap-Input vs. Conventional Technique

Source		DF	SS	MS	F-Value	P-Value	F-Critical
Between Groups		1	86759.173	86759.173	39.246	0.0033	7.71
Within Groups		4	8842.547	2210.637			

Duncan's New Multiple-Range			Mean Difference Matrix = 240.498	
			Probability Matrix = .004	
			Critical Range Matrix = 106.73	

Water Run Distance: Flap-Input vs. Float-Lift Technique

Source		DF	SS	MS	F-Value	P-Value	F-Critical
Between Groups		1	163524.95	163524.95	10.11	0.0335	7.71
Within Groups		4	64680.45	16170.11			

Duncan's New Multiple-Range			Mean Difference Matrix = 330.177	
			Probability Matrix = .034	
			Critical Range Matrix = 288.65	

Obstacle Clearance @ 50 ft. AGL: Flap-Input vs. Float-Lift Technique

Source		DF	SS	MS	F-Value	P-Value	F-Critical
Between Groups		1	1121835.856	1121835.856	9.77	0.0353	7.71
Within Groups		4	459415.004	114853.751			

Duncan's New Multiple-Range			Mean Difference Matrix = 864.807	
			Probability Matrix = .036	
			Critical Range Matrix = 769.285	

Delta Ratio~95% Level of Confidence

Flap-Input Across Weight

Source		DF	SS	MS	F-Value	P-Value	F-Critical
Between Groups		1	0.0526	0.0526	14.5893	0.0188	7.71
Within Groups		4	0.0144	0.0036			

Duncan's New Multiple-Range			Mean Difference Matrix = .187	
			Probability Matrix = .019	
			Critical Range Matrix = .136	

- Note: (1) If the mean difference matrix is greater than the critical range matrix, then the null hypothesis is rejected.
 (2) If the probability matrix is less than .05, then the null hypothesis may be rejected.

The results revealed a significant difference in several cases. They are as follows:

1. The flap-input technique demonstrated significantly shorter water-run distances at the 95% level of confidence, compared to the conventional and float-lift techniques, during heavily loaded takeoff maneuvers.
2. The flap-input technique demonstrated significantly shorter total takeoff distances at the 95% level of confidence, compared to the float-lift technique, during heavily loaded takeoff maneuvers.
3. The float-lift technique offered no significant advantage at either weight.
4. The D_R for the flap-input technique demonstrates significant difference across weight.

Delta ratios appear to be relatively consistent across weight with one exception. The flap-input technique produced a delta ratio of .61 for light weight, and .80 for gross weight – a difference of 23.8%. This difference is substantial and causes the D_R to be an impractical, and potentially dangerous, performance metric when employing the flap-input technique. Values for delta ratio regarding conventional and float-lift techniques prove the null hypothesis, they are consistent across weight, and could be applied to rule of thumb takeoff computations for seaplanes.

CONCLUSION

The purpose of this thesis was to evaluate seaplane takeoff performance with respect to delta ratio, specifically as it related to aircraft weight. To that end, a flight test was conducted to prove the consistency of the delta ratio in the takeoff performance of the Cessna A185F, N112SM. In addition, two popular seaplane takeoff techniques were evaluated for their ability to significantly reduce the takeoff distance required of a float-equipped seaplane.

The flight test developed and conducted by The University of Tennessee Space Institute resulted in the following conclusions:

1. The delta ratio demonstrated significant inconsistency across weight for the flap-input technique. This result is in opposition to previous research that found the delta ratio to be consistent across weight when using this technique.
2. The delta ratio is consistent across weight for the conventional and float-lift takeoff techniques employed during the test.
3. Compared to conventional and float-lift techniques, water-run distance is significantly reduced by the flap-input technique when the aircraft is heavy.

4. Compared to the float-lift technique, distance to the 50-foot AGL obstacle clearance-height is significantly reduced by the flap-input technique when the aircraft is heavy. However, no significant difference occurred between the conventional and flap-input technique. This supports a theory that the float-lift technique actually prolongs the takeoff in some aircraft.
5. The float-lift technique demonstrated no significant benefit at either weight.
6. A delta ratio of .68 can be applied to takeoff distance calculations for N112SM when the conventional and float-lift techniques are employed.
7. In order to generate reliable, accurate data, pilot performance must be consistent. This is particularly true in this case, as individual pilot technique (or proficiency) has a critical effect on the outcome of the takeoff maneuver.

RECOMMENDATIONS

The objective of the University of Tennessee Space Institute's flight test of the Cessna A185F Skywagon was twofold. First, to evaluate delta ratio as a metric for determining seaplane takeoff performance, and second, to assess the merits of two popular seaplane takeoff techniques used for reducing takeoff distance.

A summary of the recommendations based on this work are listed as follows:

1. The delta ratio should not be used if the intended departure includes the flap-input technique.
2. Recommend application of delta ratio to rule of thumb takeoff calculations using conventional or float-lift takeoff technique.
3. If the aircraft is heavily loaded, the flap-input technique is recommended, provided the pilot is skilled in its use and takeoff distance must be substantially shortened.
4. The float-lift technique should not be used to shorten takeoff distance in N112SM, or similarly equipped Cessna A185F.
5. Further investigation of the delta ratio should include the effect of density altitude on seaplane takeoff performance. Moreover, continued flight test evaluations of delta ratio should be performed (flown) by an engineering test pilot.

6. A larger sample of takeoff distance data is recommended in future studies of the delta ratio.
7. Recommend novice or minimum currency seaplane pilots not employ the flap-input technique.

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BIBLIOGRAPHY

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APPENDICES

Appendix A: Typical Seaplane Takeoff Thrust/Drag Chart

Appendix B: Beaufort Scale of Wind Forces

Appendix C: Rangefinder Specifications

Appendix D: Sight Gauge Illustration

Appendix E: Cessna A185F Three-View

Appendix F: Horton STOL Kit Illustrations

Appendix G: DeVore PK D3500A Float Kit Illustrations

Appendix H: Site Map w/ Crew Positions

Appendix I: Flight Test Conditions Summary

Appendix J: Takeoff Distance Data

APPENDIX A

Typical Seaplane Takeoff Performance Chart

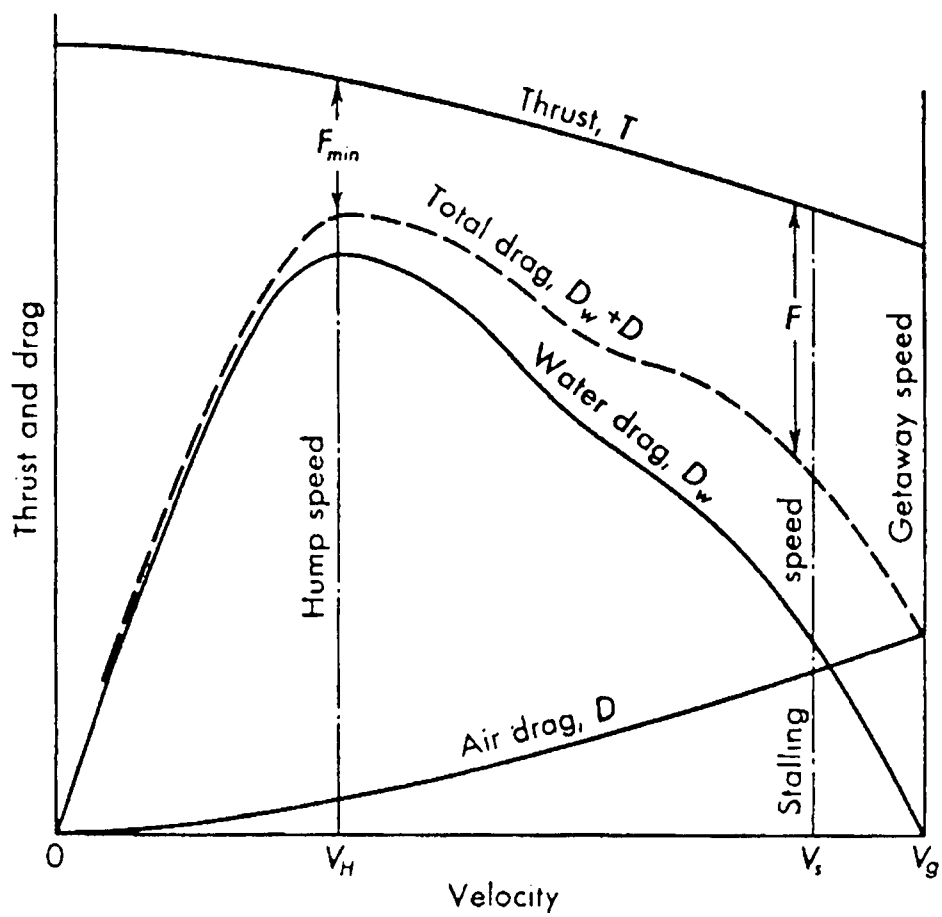


Figure A.1. Typical Drag and Thrust Curves for a Piston-Engine Seaplane.

APPENDIX B
Beaufort Scale of Wind Forces

Table B.1. Beaufort scale of wind forces revelent to seaplane operations.

Beaufort Number	Descriptive term	Mean Velocity in knots	Specifications		Probable wave height* in metres
			Sea	Coast	
0	Calm	Less than 1	Sea like a mirror	Calm	— (—)
1	Light air	1-3	Ripples with the appearance of scales are formed, but without foam crests	Fishing smack just has steerage way	0.1 (0.1)
2	Light breeze	4-6	Small wavelets, still short but more pronounced; crests have a glassy appearance and do not break	Wind fills the sails of smacks which then travel at about 1-2 knots	0.2 (0.3)
3	Gentle breeze	7-10	Large wavelets. Crests begin to break. Foam of glassy appearance. Perhaps scattered white horses	Smacks begin to careen and travel about 3-4 knots	0.6 (1)
4	Moderate breeze	11-16	Small waves, becoming longer; fairly frequent white horses	Good working breeze, smacks carry all canvas with good list	1 (1.5)
5	Fresh breeze	17-21	Moderate waves, taking a more pronounced long form; many white horses are formed. (Chance of some spray.)	Smacks shorten sail	2 (2.5)
6	Strong breeze	22-27	Large waves begin to form; the white foam crests are more extensive everywhere. (Probably some spray.)	Smacks have double reef in mainsail; care required when fishing	3 (4)
7	Near gale	28-33	Sea heaps up, and white foam from breaking waves begins to be blown in streaks along the direction of the wind	Smacks remain in harbour and those at sea lie-to	4 (5.5)

*Significant wave height is defined as the average value of the height of the largest one-third of the waves present.

Note: Use the lower code figure if the observed wave height is shown on two lines of the table, e.g. a height of 4 metres is coded as 5.

APPENDIX C
Rangefinder Specifications

Table C.1. Essco Advantage™ Laser Rangefinder

Specifications:

Weight: 4.5 lbs. – Laser Rangefinder Only

Size: 8.5 x 4.5 x 7.5 in.

Maximum Range* With Reflector: 30,000 ft. (9,188 m)

Maximum Range* Without Reflector to Cooperative Target: 2,000-ft. (600 m)

Range Accuracy: +/- 6 in.

Azimuth Range (CI Only): 0° to 359.9°

Azimuth Accuracy: level +/- 1° RMS; tilted +/- 1.5° RMS

Inclinometer Range: +/- 50°

Inclinometer Accuracy: +/- 0.4°

Eye Safety: Class 1

Beam Divergence: 3 milliradians

Wavelength: 904 nanometers

Operating Temperature: -22°F to 140°F

* Adverse atmospheric conditions may affect range capabilities.

Features:

- Heads-Up-Display (HUD)
 - Liquid Crystal Display (LCD)
 - RS232 Serial Port
 - 2MB Memory via PCMCIA Type II SRAM
 - Digital Compass – Three Axis Magnetometer;
Single Board (2.5" Wide x 1.5" Long x 1" Tall)
 - Fluid Level Inclinometer
-

APPENDIX D

Sight Gauge Illustration

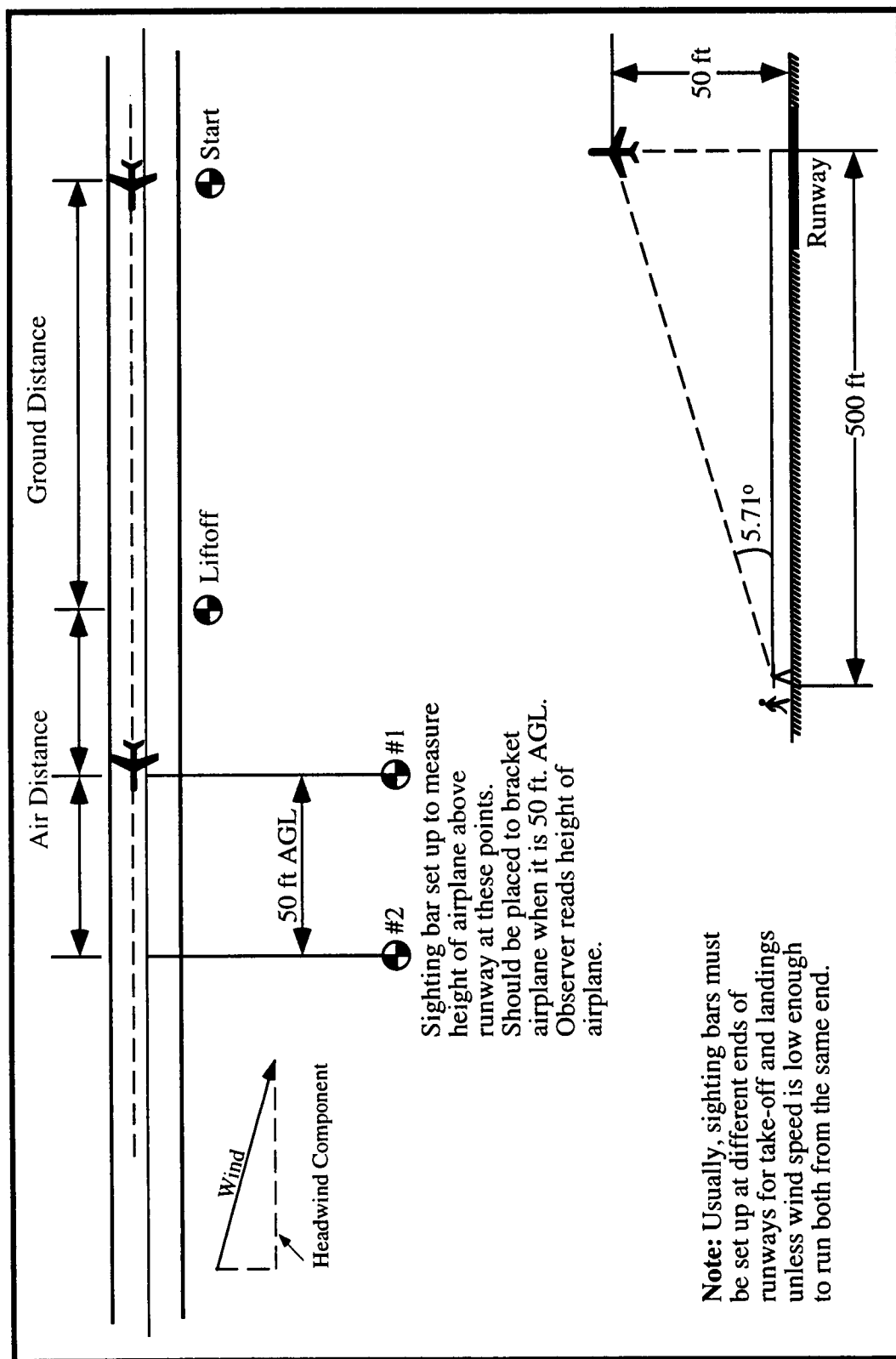


Figure D.1. Sight Gauge Illustration.

APPENDIX E

Cessna A185F Three-View

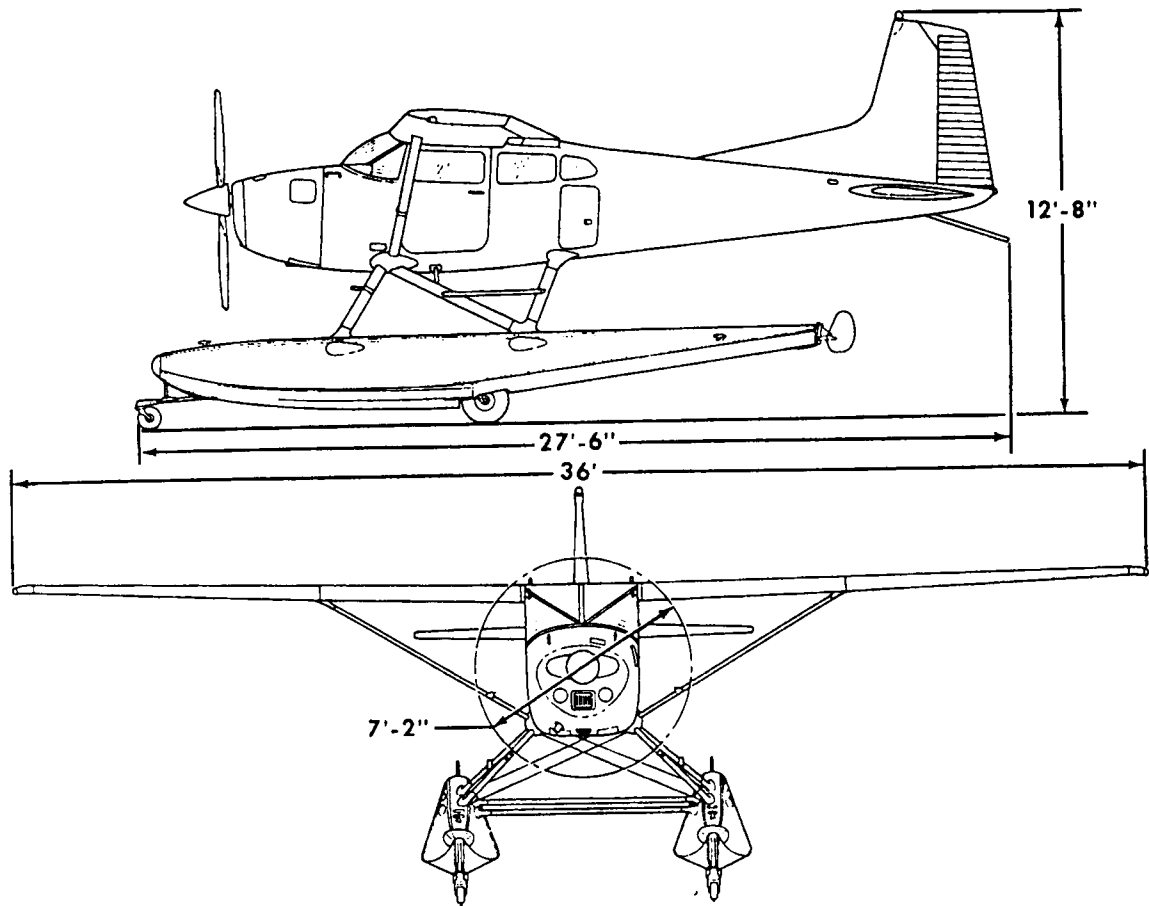


Figure E.1. Cessna A185F Three-View.

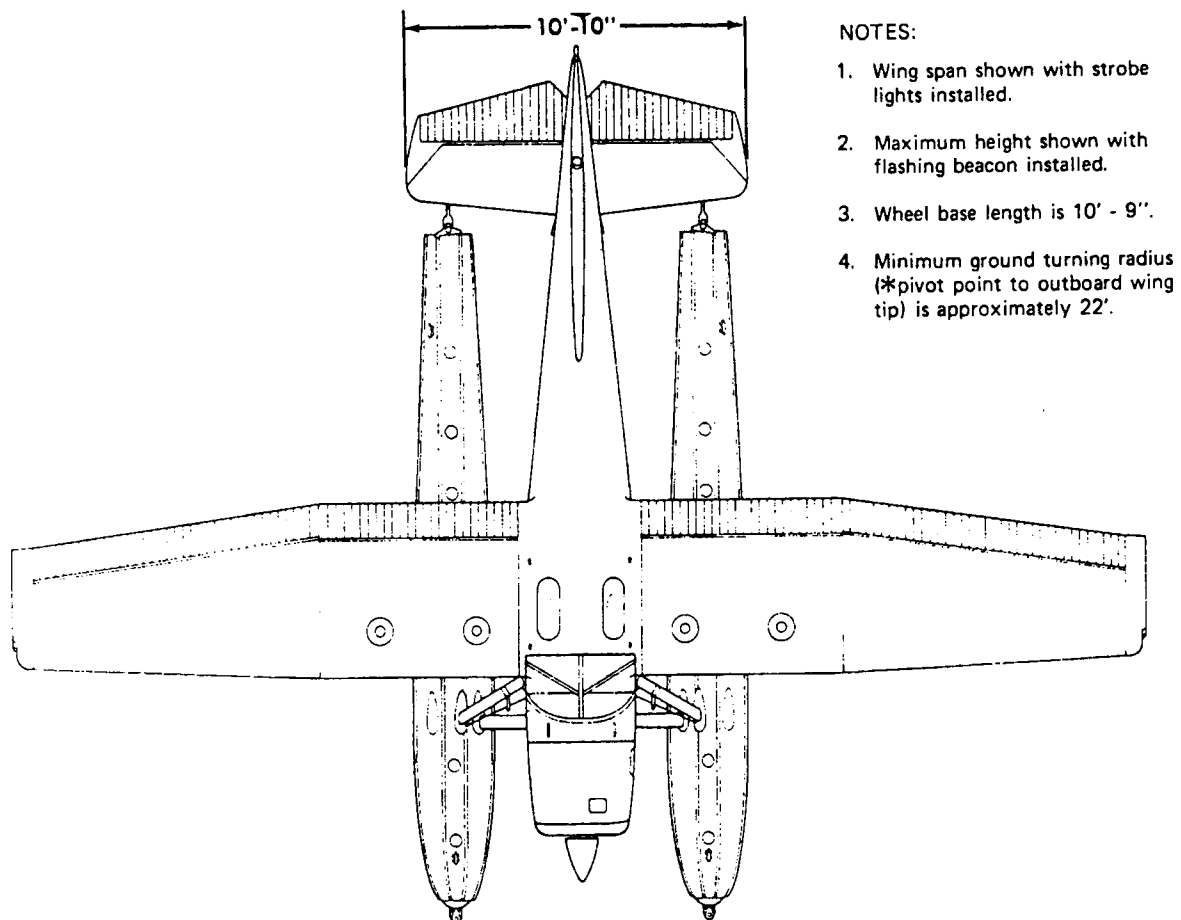


Figure E.1. Cessna A185F Three-View (cont.).

APPENDIX F
Horton STOL Kit Illustrations

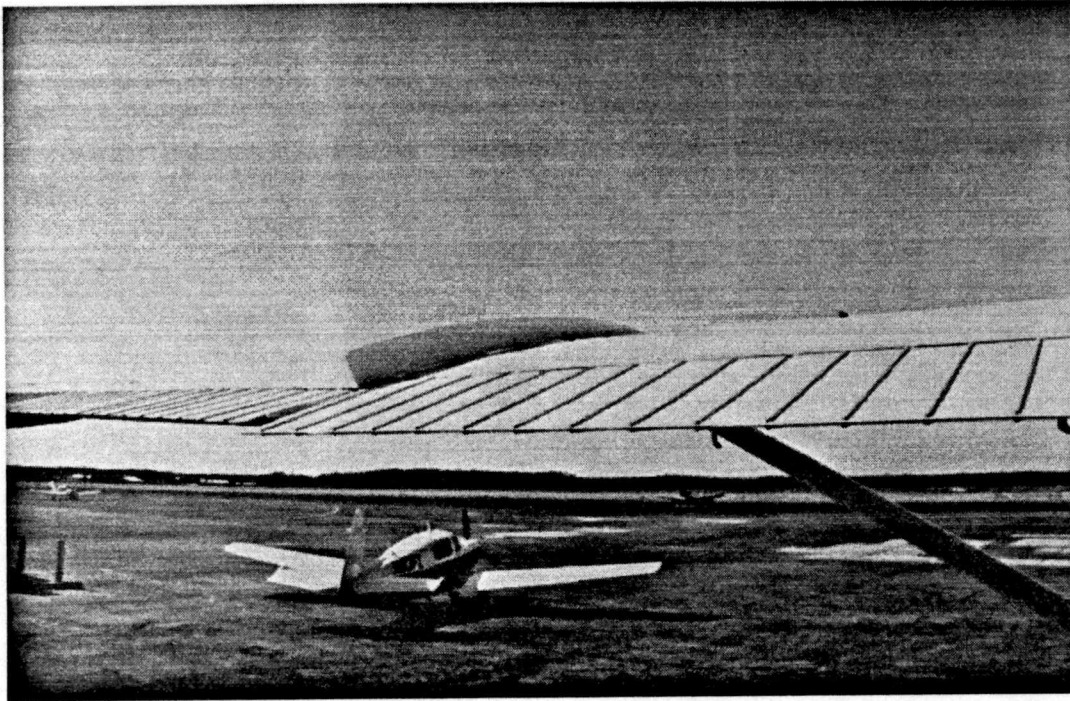


Figure F.1. Port Wing Stall Fence.

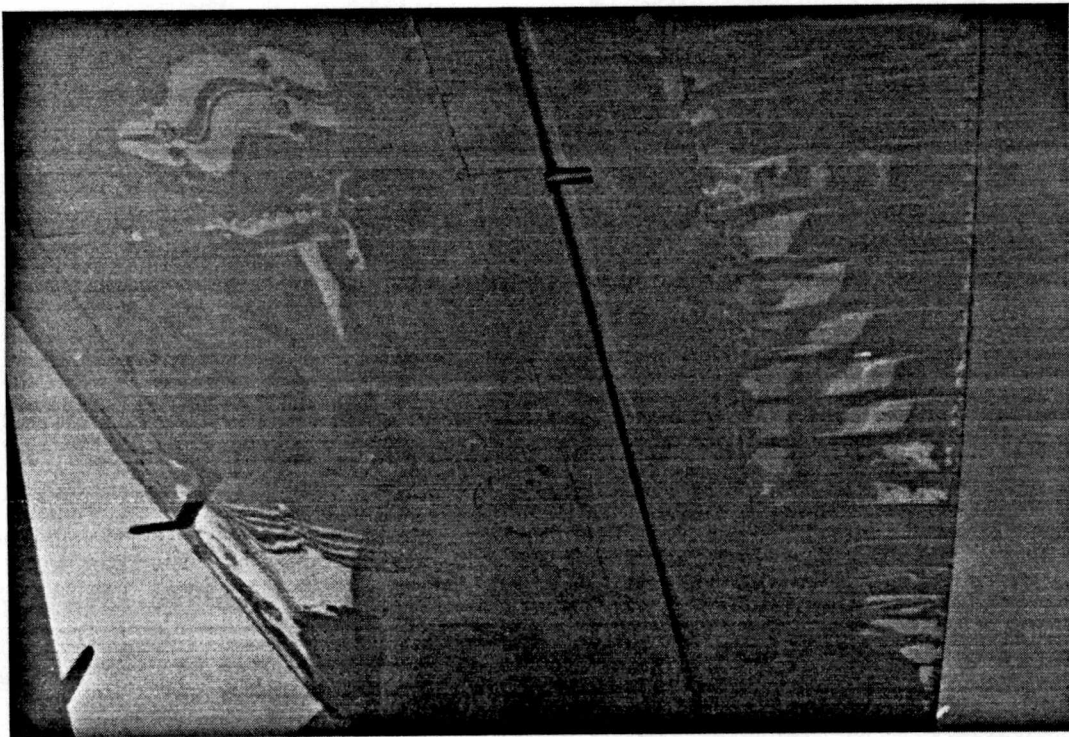


Figure F.2. Port Wing Flap Gap Seal.

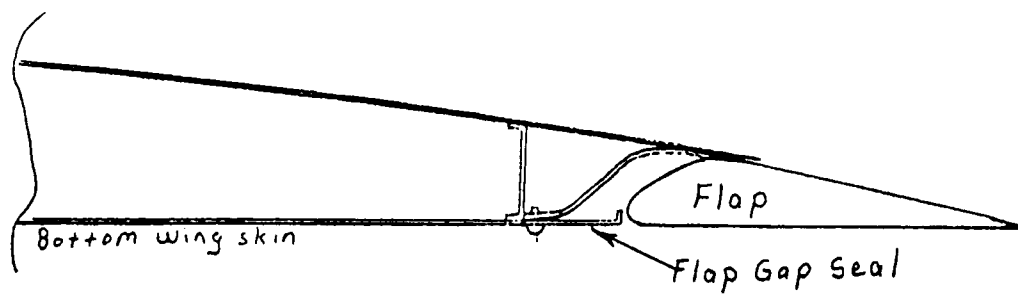


Figure F.3. Flap Gap Seal Installation.

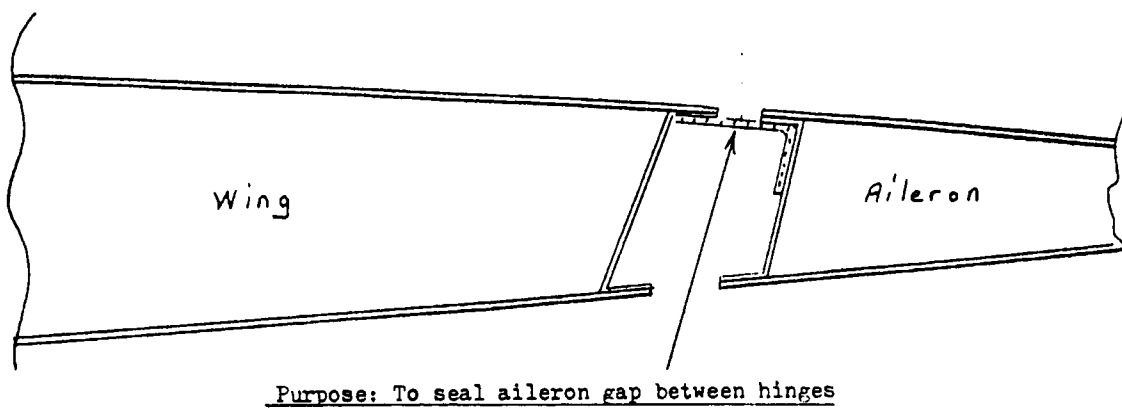


Figure F.4. Aileron Gap Seal Installation.

APPENDIX G

DeVore PK D3500A Float Kit Illustrations



Figure G.1. PK D3500A Floats.

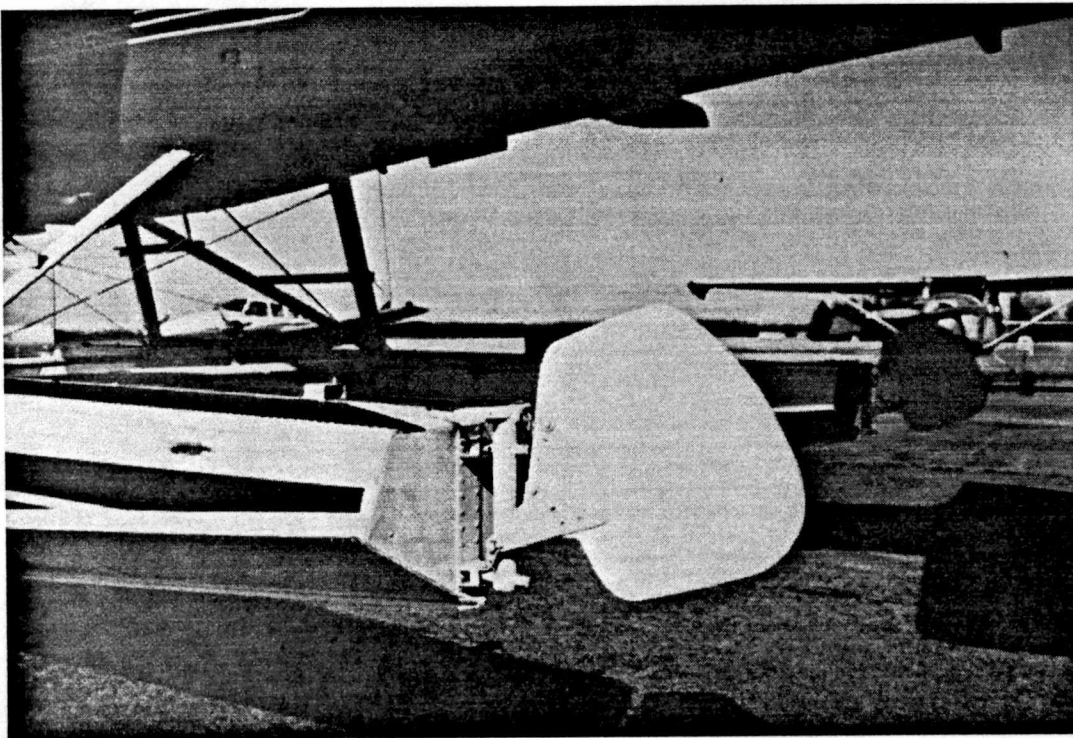


Figure G.2. Water Rudders (Up Position).

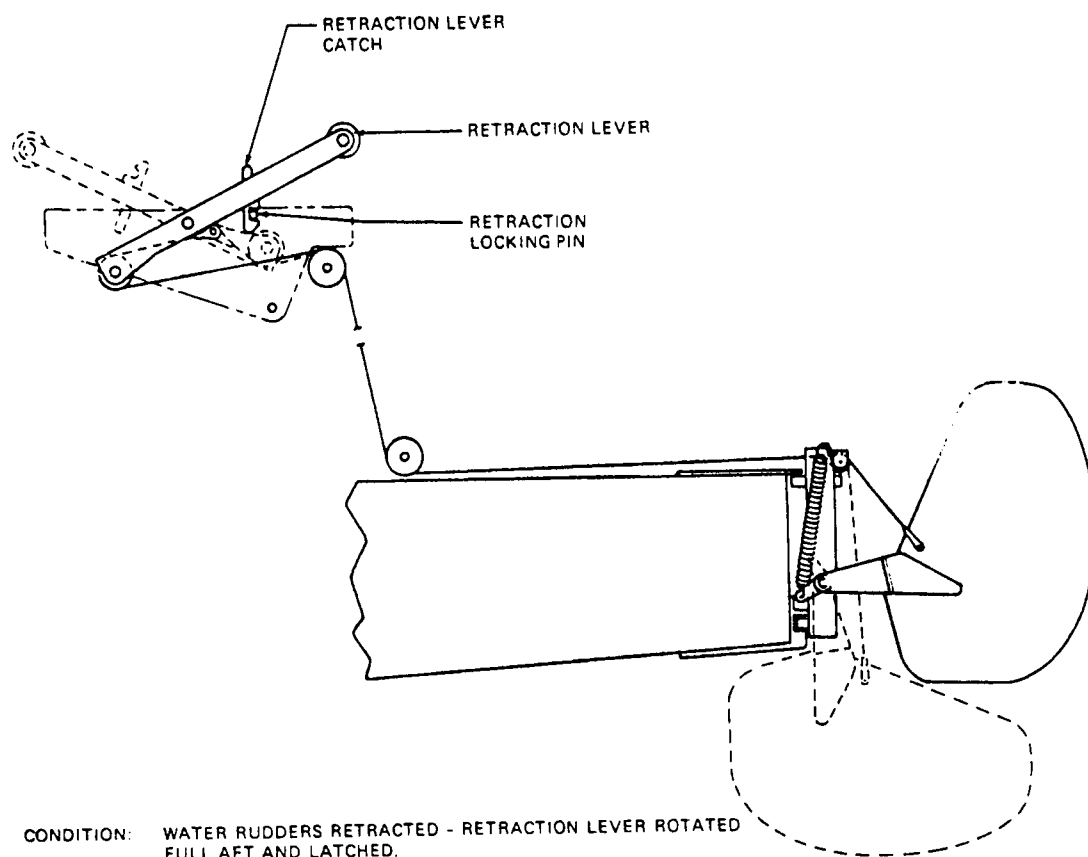


Figure G.3. Water Rudder Retraction System.

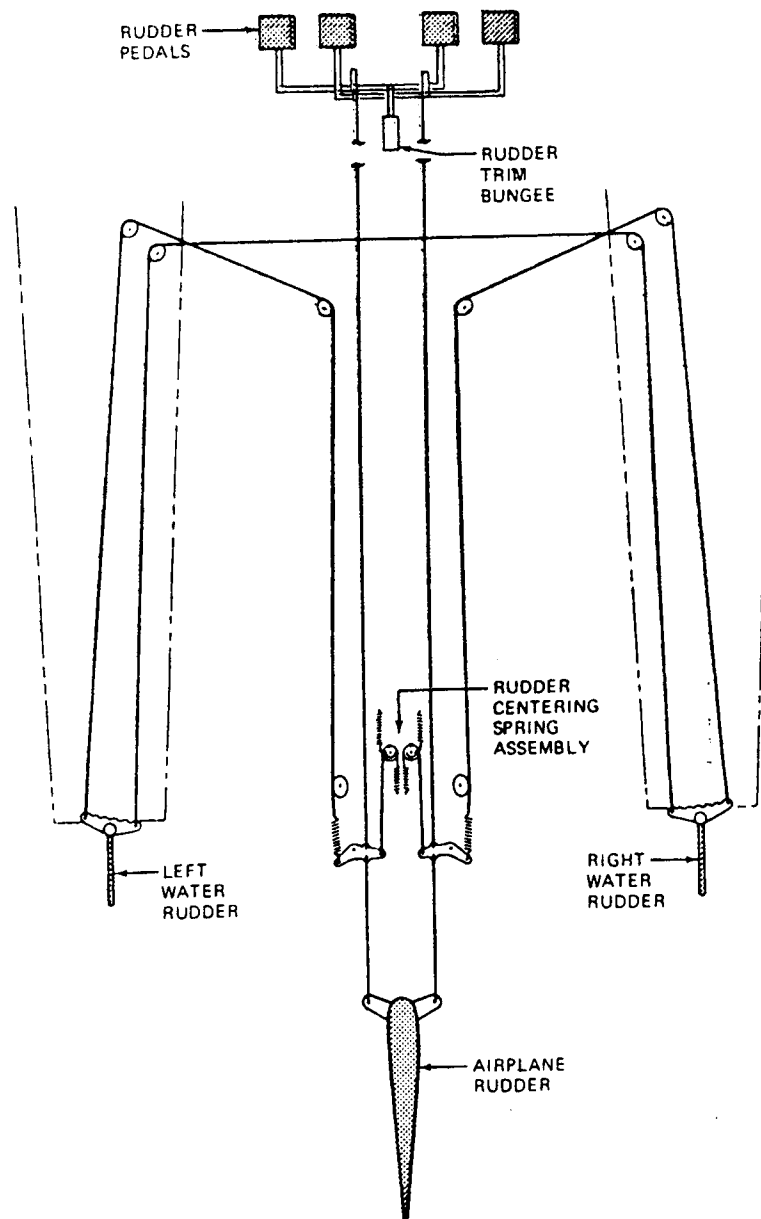


Figure G.4. Water Rudder Steering System.

APPENDIX H
Site Map w/ Crew Positions

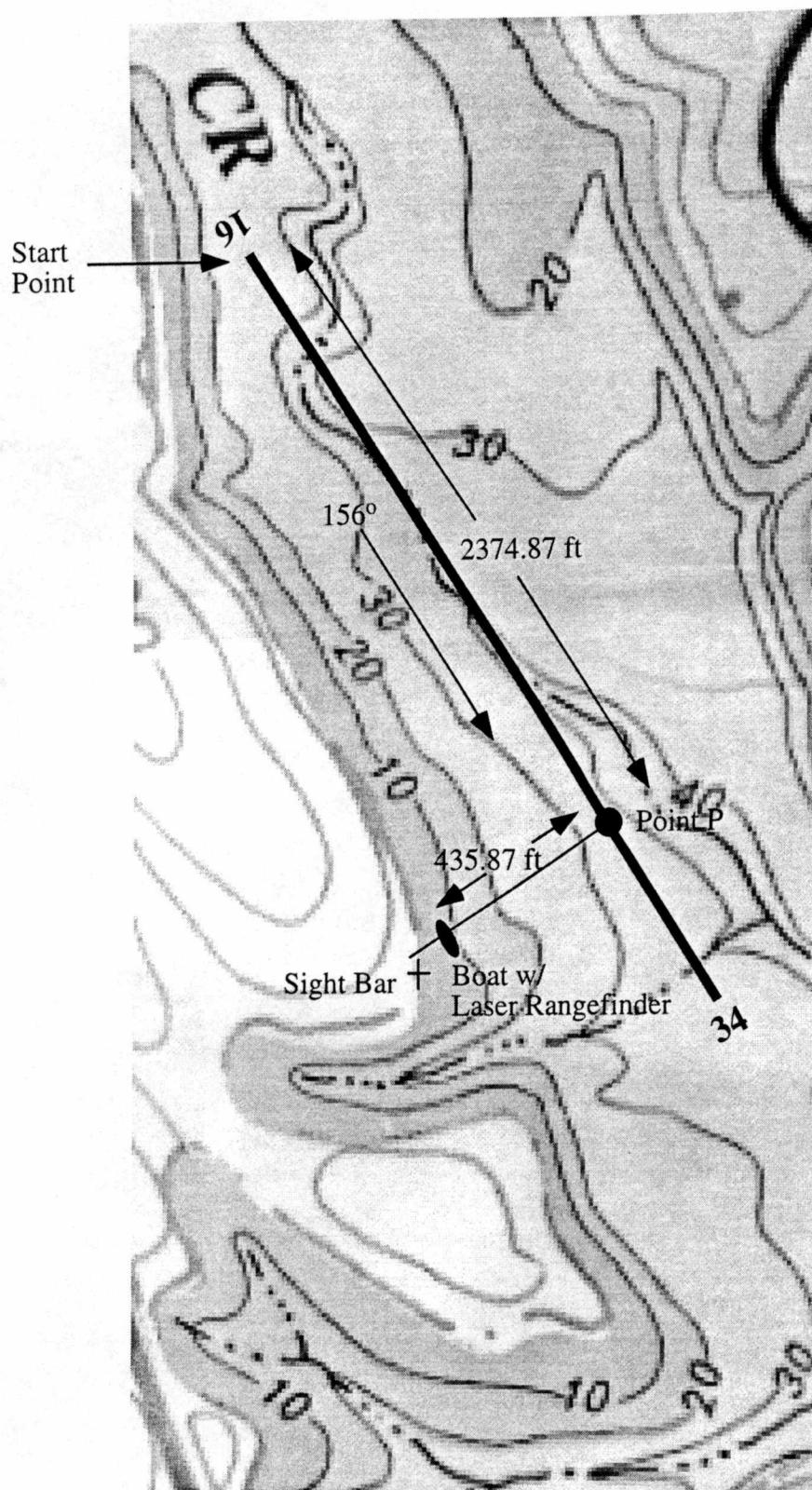


Figure H.1. Site Map w/Crew Location.

APPENDIX I
Flight Test Conditions Summary

Table I.1. Flight Test Conditions Summary

Date: 16-Dec-97

Model: 1977 Cessna A185F Skywagon

Registration #: N112SM

Configuration: Takeoff (20 deg. of flap)

Power: RPM 2850; MP 28 in. Hg.

Location: Rollins Creek, Woods Reservoir (THA)

Takeoff Weight: 3067.08 lb.

C.G. @ Takeoff: 40.10 in.

Note: (1) All pitot-static information was collected from the pilot's panel.

(2) The altimeter, manifold pressure, and tachometer were not calibrated.

Pilot: J. Hunt

Observer: W. Waters

Total Time: 1.8 Hrs.

Light Weight

Data Set #1	WS (knots)	WD (deg.)	Hpi (ft)	OATi (F)	OAT (C)	BHP _T
Surface	Light	Variable	720	47	8.3	284.21
50 ft. AGL	3	223 SSW	770	47	8.3	284.16
Fuel Used (Gallons): 2.9						
Data Set #2	WS (knots)	WD (deg.)	Hpi (ft)	OATi (F)	OAT (C)	BHP _T
Surface	Light	Variable	720	48	8.9	283.94
50 ft. AGL	3	223 SSW	770	48	8.9	283.89
Fuel Used (Gallons): 2.6						
Data Set #3	WS (knots)	WD (deg.)	Hpi (ft)	OATi (F)	OAT (C)	BHP _T
Surface	Light	Variable	720	51	10.6	283.15
50 ft. AGL	3	223 SSW	770	51	10.6	283.1
Fuel Used (Gallons): 2.4						

Gross Weight

Data Set #4	WS (knots)	WD (deg.)	Hpi (ft)	OATi (F)	OAT (C)	BHP _T
Surface	Light	Variable	760	54	12.2	280.37
50 ft. AGL	3	223 SSW	810	54	12.2	280.36
Fuel Used (Gallons): 3.8						
Data Set #5	WS (knots)	WD (deg.)	Hpi (ft)	OATi (F)	OAT (C)	BHP _T
Surface	Light	Variable	760	56	13.3	279.85
50 ft. AGL	3	223 SSW	810	56	13.3	279.84
Fuel Used (Gallons): 2.6						
Data Set #6	WS (knots)	WD (deg.)	Hpi (ft)	OATi (F)	OAT (C)	BHP _T
Surface	Light	Variable	760	57	13.9	279.59
50 ft. AGL	3	223 SSW	810	57	13.9	279.58
Fuel Used (Gallons): 3.1						

APPENDIX J
Flight Test Data Table

Table J.1. Takeoff Distance Data

Light Weight

	<i>Conventional Takeoff</i>				
Takeoff #	1	4	7	SUM	AVG
Liftoff	1264.5	1142.8	1100.42	3507.72	1169.24
50-ft. AGL	1540.11	1731.65	1877.92	5149.68	1716.56
DR	0.8210453	0.6599486	0.5859781	0.681153	0.681153
	<i>Float-Lift Takeoff</i>				
Takeoff #	2	5	8	SUM	AVG
Liftoff	1379.28	1176.4	1244.3	3799.98	1266.66
50-ft. AGL	1862.59	1884.01	1841.17	5587.77	1862.59
DR	0.7405172	0.6244128	0.6758203	0.680053	0.680053
	<i>Flap-Input Takeoff</i>				
Takeoff #	3	6	9	SUM	AVG
Liftoff	1049.87	1155.92	1098.82	3304.61	1101.5367
50-ft. AGL	1792.03	1645.29	2010.02	5447.34	1815.78
DR	0.5858551	0.7025631	0.5466712	0.6066465	0.6066465

Gross Weight

	<i>Conventional Takeoff</i>				
Takeoff #	10	13	16	SUM	AVG
Liftoff	2400.77	2350.5	2375.64	7126.91	2375.6367
50-ft. AGL	3884.98	3201.57	2613.44	9699.99	3233.33
DR	0.617962	0.734171	0.9090088	0.7347337	0.7347337
	<i>Float-Lift Takeoff</i>				
Takeoff #	11	14	17	SUM	AVG
Liftoff	2526.66	2595.04	2274.24	7395.94	2465.3133
50-ft. AGL	3990.28	3585.62	3035.9	10611.8	3537.2667
DR	0.6332037	0.7237354	0.7491156	0.6969543	0.6969543
	<i>Flap-Input Takeoff</i>				
Takeoff #	12	15	18	SUM	AVG
Liftoff	2124.23	2079.76	2201.42	6405.41	2135.1367
50-ft. AGL	2656.85	2688.07	2672.46	8017.38	2672.46
DR	0.7995295	0.7737001	0.8237429	0.7989406	0.7989406

* Note: Highlighted data eliminated with 90% confidence of rejection via the Grubbs Test for outliers and replaced with the mean value of the two remaining terms.

VITA

William Bryan Waters Jr. was born in Norfolk, Virginia on September 13, 1969. He attended elementary school in Virginia Beach and graduated from Norfolk Collegiate High School in 1987. Just prior to the start of his junior year in high school, he began flight training and soloed in July of 1985. While studying in Norfolk at Old Dominion University, he earned his Private, Instrument, Commercial, and Instructor pilot certificates. Graduating with a Bachelor of Science Degree in Psychology in 1992, he continued in his capacity as event manager with Norfolk Festevents, Ltd., an agency charged with promoting the Downtown Norfolk Waterfront. In August 1994 he began the Aerospace Maintenance Program at Middle Tennessee State University. While in attendance at MTSU, he added the multi-engine rating to his pilot's license, worked as a banner tower pilot in the resort areas of Virginia Beach and Ocean City, MD, and earned his Airframe and Powerplant Mechanic certificates in 1996. Having recently checked out in single-engine seaplanes, he has flown over 1500 hours in over 30 different aircraft types and is currently employed as a pilot with AVIAD Corporation of Boston, MA. William graduated from the University of Tennessee Space Institute in May 1998 with a Master of Science Degree in Aviation Systems.