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Flight Test Evaluation Of Piper Seminole

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FLIGHT TEST EVALUATION OF PIPER SEMINOLE

by

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Abstract

FLIGHT TEST EVALUATION OF PIPER SEMINOLE

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After taking FTE 5702 – Stability and Control class, taught by Dr.Kimberlin, I understood the concept of using an aircraft and then testing how it handles in the air. Almost all flight tests done on aircraft are done by the manufacturer. Some aircraft may have a lot of comprehensive information available, while others have little to no information. It can also be hard to find the specific data that a pilot or owner desires. These various tests allow a greater understanding of aircraft stability and performance available for analysis and relating.

The aircraft I flew during FTE 5702 class was a Piper PA-32 Cherokee Six. This was a single-engine piston. I currently have an FAA Commercial Multi-Engine pilot license. Can these tests be done on a multi-engine piston aircraft and retrieve reliable data? This led to the interest in conducting stability and control testing on a piston multi-engine aircraft.

This thesis presents similar methods and concepts done according to Dr.Kimberlin's Flight Test of Fixed-Wing Aircraft procedures. Testing shall be conducted on a multi-engine piston aircraft. Testing is according to meet part 23 regulations. Completing these tests shall provide a better idea of the operational safety and limitations of a multi-engine aircraft, and which areas might need to be redefined in the Part 23 Regulations to enhance the safety of the General Aviation Industry and its Pilots.

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List of Abbreviations

A.C.	Aerodynamic Center
CL	Coefficient of Lift
ATIS	Automatic Terminal Information Services
C.G.	Center of Gravity
DAQ	Data Aquision
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulaiton
POH	Pilot Operating Handbook
PIM	Pilot Information Manuel
FIT	Florida Insitiute of Technology
FTE	Fligth Test Engineering
FTP	Flight Test Pilot
LOC	Lost of Control
KIAS	Knots indicated air speed
PIC	Pilot in Command
RPM	Revolutions per minute
LBS	Weight in pounds
CAS	Calibrated Air Speed
Min	Time in munites
VMC	Minimum Control Speed
AOA	Angle Of Attack

List of Symbols

V_{s0}	Stall Speed in Landing configuration
V_{s1}	Stall Speed in Clean configuration
V_{FE}	Maximum speed for Flaps Extended
V_{MC}	Minimum Control Airseed with One Engine
W_{NDR}	Undamped Natural Frequency
W_{DDR}	Damped Natural Frequency
q	Dynamic Pressure

Acknowledgement

I would like to thank God for carrying me through my education journey from day one. I also would like to express a big thank you to my academic advisor and program chair of the FTE department, Brian Kish, without whom I could have never made it through my coursework and research. He has supported me throughout my endless questions and provided me with insight information though my grad school career.

I would also like to thank Dr.Ralph Kimberlin, who has also been part of my graduate thesis committee and taught me many interesting things about Flight Testing throughout the course that I have taken with him.

Thank you to FIT Aviation for approving the flights to be taken place for this research. I appreciate crew members Ridwan Oladipupo Olabanji for flight guidance of the Seminole and Sean Gunther for collecting data.

I would also like to thank all the other professors and mentors who have guided me throughout my undergraduate and graduate years here at Florida Tech. I would have not come this far without you all.

Dedication

I would like to dedicate this work to my parents. Without them, I definitely would not have gotten to this point in my education and career. First teaching me the fundamentals of life and how to carry myself as a proper young man is how I can use my determination to succeed in what I love to do. They believed in my goals and had no questions regarding my success. Thank you for continuously encouraging me to be the best at what I love.

Chapter 1
Introduction

1.1 Background

As a multi-engine commercial pilot, I have conducted numerous flight lessons to familiarize myself with how these types of aircraft perform. To earn these pilot licenses, applications must conduct various maneuvers to show mastery of the aircraft.

Most maneuvers have limitations associated with the aircraft because of how it was designed. Stalls, Vmc demo, engine failures, and other maneuvers are conducted to ensure the flight can be conducted safely. When operating two engines instead of one, it is expected for the aircraft to likely be less forgiving than a single-engine piston aircraft with similar powerplants.

The stability and control of muli-engine aircraft are very critical. Certain phases of flight can cause these aircraft to lose their controllability and make it difficult for pilots to make command inputs. Knowing the stability limitations of muli-engines can give a proper picture as to how to conduct certain maneuvers and how pilots should conduct flights variously.

1.2 Motivation

This thesis will present the testing procedures, and experimental results, and discuss and analyze the meaning of the collected data from the multi-engine aircraft. Additionally, any recommendations that the flight test engineers have will be listed in the conclusion of this report.

The chapters of this report are organized as follows: Chapter 1 of this will focus on the purpose of this research and talk about the reason behind the testing that is being conducted. Proper reason to show why conducting testing would be beneficial.

Chapter 2 will talk about the test aircraft, equipment, and how data was collected. Chapters 3 and 4 will focus on the data that has been collected and analyze it. Chapter 4 will conclude the thesis, and provide recommendations for areas that can be approved and state limitations present.

1.3 FAA Guidance

According to the current CFR § 23.2145 - Stability:

(a) Airplanes not certified for aerobatics must -

(1) Have static longitudinal, lateral, and directional stability in normal operations;

(2) Have dynamic short period and Dutch roll stability in normal operations; and

(3) Provide stable control force feedback throughout the operating envelope.

(b) No airplane may exhibit any divergent longitudinal stability characteristic so unstable as to increase the pilot's workload or otherwise endanger the airplane and its occupants.

This current FAR does not give exact specifics as to stability requirements. However, the old FAR did provide more specifics for testing.

CFR § 23.173 -Static longitudinal stability (From effective date:12/20/1973)

Under the conditions specified in Sec. 23.175 and with the airplane trimmed as indicated, the characteristics of the elevator control forces and the friction within the control system must be as follows:

(a) A pull must be required to obtain and maintain speeds below the specified trim speed and a push required to obtain and maintain speeds above the specified trim speed. This must be shown at any speed that can be obtained, except that speeds requiring a control force in excess of 40 pounds or speeds above the maximum allowable speed or below the minimum speed for steady unstalled flight, need not be considered.

(b) The airspeed must return to within plus or minus 10 percent of the original trim speed when the control force is slowly released at any speed within the speed range specified in paragraph (a) of this section.

(c) The stick force must vary with speed so that any substantial speed change results in a stick force clearly perceptible to the pilot.

CFR § 23.181 Dynamic stability. (effective date 09/14/69)

(a) Any short period oscillation not including combined lateral-directional oscillations occurring between the stalling speed and the maximum allowable speed appropriate to the configuration of the airplane must be heavily damped with primary controls--

(1) Free; and

(2) In a fixed position.

(b) Any combined lateral-directional oscillations ("Dutch roll") occurring between the stalling speed and the maximum allowable speed appropriate to the configuration of the airplane must be damped to amplitude in 7 cycles with the primary controls--

(1) Free; and

(2) In a fixed position.

[(c) If it is determined that the function of a stability augmentation system, reference Sec. 23.672, is needed to meet the flight characteristic requirements of this part, the primary control requirements of paragraphs (a)(2) and (b)(2) of this section are not applicable to the tests needed to verify the acceptability of that system.

(d) During the conditions as specified in Sec. 23.175, when the longitudinal control force required to maintain speeds differing from the trim speed by at least ±15 percent is suddenly released, the response of the airplane must not exhibit any dangerous characteristics nor be excessive in relation to the magnitude of the control force released. Any long-period oscillation of flight path, phugoid oscillation, that results must not be so unstable at to increase the pilot's workload or otherwise endanger the airplane.]

The older FAR gave more details as to what is expected. The more specific contidions are easier to evaluate when conducting testing.

According to current CFR § 32.2135 (c):

(c) VMC is the calibrated airspeed at which, following the sudden critical loss of thrust, it is possible to maintain control of the airplane.

Just like other regulations, the older FAR rule gave more details on the requirements. The current FAR does not give exact specifics of the stability requirements for VMC.

Minimum Control Speed (Efective date 03/01/1978)

[(a) VMC is the calibrated airspeed, at which, when the critical engine is suddenly made inoperative, it is possible to recover control of the airplane with that engine still inoperative, and maintain straight flight either with zero yaw or, at the option of the applicant, with an angle of bank of not more than five degrees. The method used to simulate critical engine failure must represent the most critical mode of powerplant failure with respect to controllability expected in service.

(b) For reciprocating engine-powered airplanes, VMC may not exceed 1.2 (where is determined at the maximum takeoff weight) with--

(1) Takeoff or maximum available power on the engines;

(2) The most unfavorable center of gravity;

(3) The airplane trimmed for takeoff;

(4) The maximum sea level takeoff weight (or any lesser weight necessary to show VMC);

(5) Flaps in the takeoff position;

(6) Landing gear retracted;

(7) Cowl flaps in the normal takeoff position;

(8) The propeller of the inoperative engine--

(i) Windmilling;

(ii) In the most probable position for the specific design of the propeller control; or

(iii) Feathered, if the airplane has an automatic feathering device: and

(9) The airplane airborne and the ground effect negligible.

(c) For turbine engine-powered airplanes, VMC may not exceed 1.2 (where is determined at the maximum takeoff weight) with--

(1) Maximum available takeoff power or thrust on the engines;

(2) The most unfavorable center of gravity;

(3) The airplane trimmed for takeoff;

(4) The maximum sea level takeoff weight (or any lesser weight necessary to show VMC);

(5) The airplane in the most critical takeoff configuration, except with the landing gear retracted; and

(6) The airplane airborne and the ground effect negligible.

(d) At VMC, the rudder pedal force required to maintain control may not exceed 150 pounds, and it may not be necessary to reduce power or thrust of the operative engines. During recovery, the airplane may not assume any dangerous attitude and it must be possible to prevent a heading change of more than 20 degrees.]

This thesis will look at both old and new regulations to examine if the aircraft satisfy controllability requirements.

1.4 VMC

VMC (Mininim controllable airspeed) is defined in CFR § 32.215. It is the minimum published airspeed that the aircraft can be controllable if an engine was to be lost. The specific VMC speed will vary by many configurations and conditions. Pilots go through countless training flying one-engine operations on multi-engine aircraft.

The two main types of VMC are Static VMC and Dynamic VMC. Static VMC is the VMC speed that is determined in a static stability configuration. Dynamic VMC is VMC under dynamic conditions. For example, the aircraft must regain control dynamically within 20 degrees and no more than 5 degrees of a bank is needed after sudden engine failure. The VMC published is usually the higher of the two speeds.

Published VMC is marked as a red line on the airspeed indicator. Published Vmc is close to the worst-case scenario under standard conditions. Depending on the conditions and configuration of the aircraft, the actual VMC may be different. Actual Vmc may be lower, especially after feathering the inoperative engine's propeller. This is why pilots should not assume being above the published VMC will garentee safety at all times. VMC may be higher than you assume it is.

Conditions by which Vmc for takeoff is determined by the manufacturer for certification of the airplane:
(FAR 23.149. Airplane Flying Handbook p. 12-28)

1. Standard atmosphere. (FAR 23.45)
2. Most unfavorable CG and weight.
3. Out of ground effect.
4. Critical engine INOP.
5. Bank no more than 5° towards operating engine.
6. Max available takeoff power on each engine initially.
7. Trimmed for takeoff.
8. Wing flaps set to takeoff position.
9. Cowl flaps set to takeoff position.
10. Landing gear retracted.
11. All propeller controls in takeoff position. (INOP engine windmilling)
12. Rudder force required by the pilot to maintain control must not exceed 150 pounds.
13. It must be possible to maintain heading ±°20.

These rules were presented in the older VMC regulation. Below is a table showing how VMC can change based on different conditions and configurations.

Table 1. Table Showing VMC Factors

Factors	**VMC**	**Performance**
Increase in density altitude	Decreases (good)	Decreases (bad)
Increase in weight	Decreases (good)	Decreases (bad)
Windmilling prop (vs feathered)	Increase (bad)	Decreases (bad)
AFT CG	Increase (bad)	Increase (Good)
Flaps extended	Decreases (good)	Decreases (bad)
Gear retracted	Increase (bad)	Increase (Good)
Up to 5 degrees bank towards the good engine	Decreases (good)	Increase (Good)

If a pilot can not input more rudder force, the controllability of the aircraft is in jeopardy with an engine failure. No more rudder authority can take place if the deflection requires more input. The rudder authority is crucial in order to maintain the stability of the aircraft during an engine failure.

1.5 Critical Engine

Most GA multi-engine aircraft have a critical engine. According to the FAA, "The critical engine is the engine whose failure would most adversely affect the airplane's performance or handling qualities." If the critical engine was to fail on a multi-engine aircraft, then the aircraft would be harder to control than the other engine. For example, in twin-engine airplanes with both engines turning in a conventional, clockwise rotation, the left engine is said to be the critical engine. The four factors that make the left engine critical on a conventional multi-engine aircraft are P-Factor (asymmetric thrust), Accelerated slipstream, Spiraling slipstream, and Torque.

<u>P-Factor(yaw)</u>

On high angles of attack, the descending blade produces more thrust than the ascending blade. Looking at figure 1, the descending, right, blade on the right engine has a longer arm from the CG than the descending right blade of the left engine. If the left engine was to fail, then it would be harder for pilots to control the aircraft. The figure below shows how the critical engine is more effective on controllability.

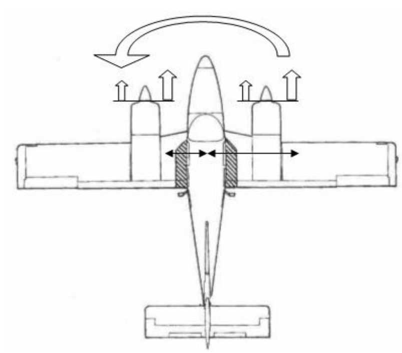

Figure 1 Showing P-Factor Effect

Accelerated Slipstream (roll and pitch)

More induced lift is created on the right side of the right engine than on the left side of the left engine by the prop wash. This is associated with the p-factor. The right engine has a greater force since it has a greater arm than the CG. Because of this, the critical engine will create more adverse conditions.

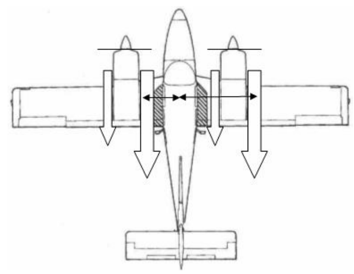

Figure 2 Showing Accelerated Slipstream

Spiraling Slipstream

The spiraling slipstream from the left engine hits the tail from the left. In case of a right engine failure on a conventional muliti-engine aircraft, this tail force will counteract the yaw towards the left dead engine. If the left engine was to fail, then there would be no slipstream making contact with the tail. This means yaw can not be counteracted, thus there is a greater loss of directional control.

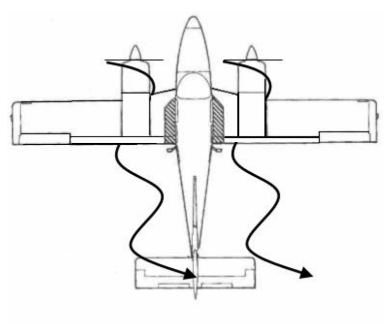

Figure 3 Showing Spiraling Slipstream

Torque

According to Newton's 3rd law of motion, for every action, there is an equal and opposite reaction. As a result of the propellers turning clockwise on a multi-engine aircraft, there is a left rolling tendency of the airplane. If the right engine fails, this left roll tendency will help maintain control and resist the right roll towards the right, dead engine. If the left engine fails, the left roll tendency by torque will add to the left turning force caused by asymmetric thrust, making it much more difficult to maintain directional control. This makes the left engine critical.

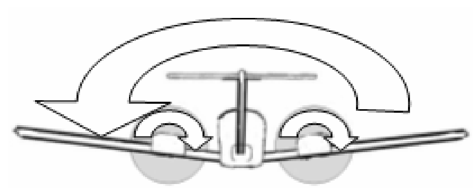

Figure 4 Showing Torque

The Piper Seminole has an interest because it is unique in the sense that it has counter-rotating propellers. This means the propellers are rotating opposite each other. Unlike a conventional multi-engine with a critical engine, the piper Seminole does not have a critical engine. Theoretically, both engines should behave the same and have the same effect if one was to fail. On a counter-rotating multi-engine aircraft, no matter which engine fails, torque will oppose the roll created by asymmetric thrust. Forces that are produced are relatively the same.

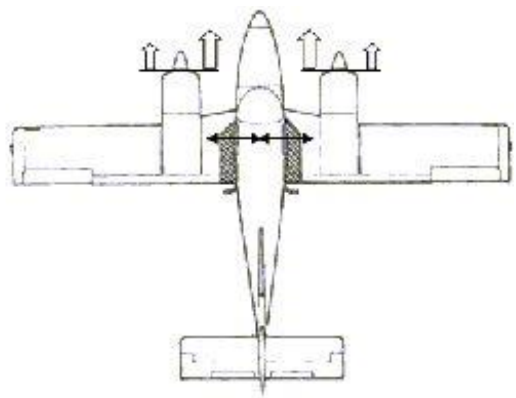

Figure 5 Showing P-Factor

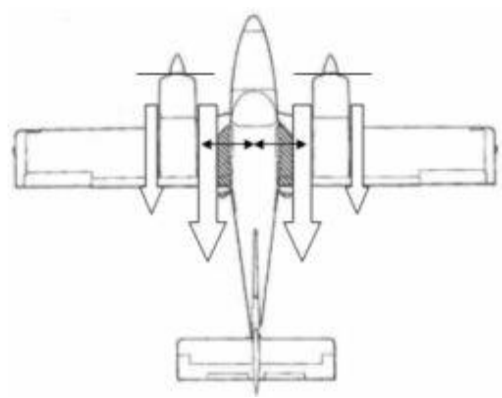

Figure 6 Showing Accelerated Slipstream

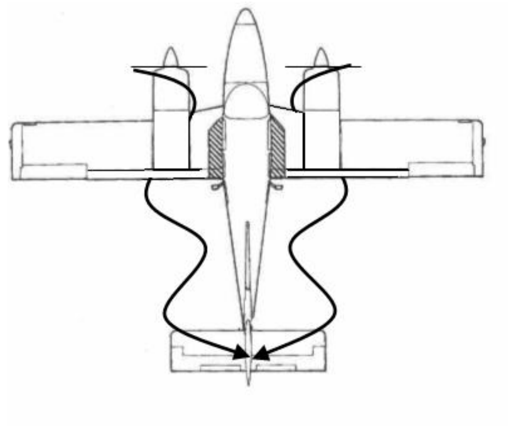

Figure 7 Showing Spiral slipstream

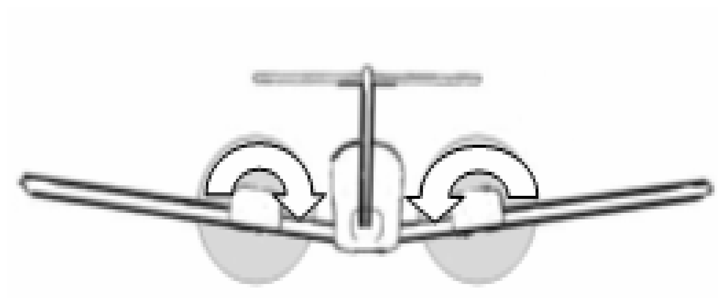

Figure 8 Showing Torque

Chapter 2
Test Aircraft, Data Collection Methods, and Test Location

2.1 Test Aircraft

To test the stability and control of a multi-engine, a Piper Seminole Pa-44-180 was used. This aircraft is currently used by Florida Tech Aviation to train student pilots for commercial and flight instructor ratings. The Piper Seminole is a four-seat, twin-engine passenger aircraft, which is powered by two, four-cylinder Lycoming 180hp engines. The aircraft is equipped with retractable gears and constant speed propellers. Flaps are extended on the aircraft by using a manual flap lever located between the two front seats. The aircraft has counter-rotating propellers. The Seminole max rudder deflection is 37 degrees left and right.

Figure 9 Showing Piper Seminole

2.2 Data Collection Methods

To successfully collect all the required data needed for this thesis, the flight test engineers used easily accessible instruments such as airspeed indicator, altimeter, attitude indicator, stick force gauges, rudder force gauges, Stratus, and GoPro Cameras to require what happened on the test flights without necessarily completing additional flights. Data was recorded using flight cards and using Stratus. After recording the data, the results were sorted, then placed in an Excel sheet and evaluated and analyzed. From these interpretations, conclusions and future recommendations were made.

During each flight, test data collection shall be both manually recorded and from the hand-held computer tablet that displayed the ADS-B data in real-time. Data shall be recorded in flight on kneeboard test run cards and also automatically recorded by the ADS-B when turned on by the flight crew. Additional qualitative data collection shall also be gathered through photos and videos taken by the flight crew using personal smartphones from various manufacturers and mounted inside Go Pros. I was the test pilot conducting the maneauvers while other crew members collected data and provided other assistance.

2.2.1 Force Gauge

Force indicator shall be used for “ Longitudinal Static Stability” test. It is used to measure the forward or back force applied on the yoke. The gauge is simply placed on to the yoke while flying the aircraft, and as pressure is applied, a reading is provided on the gauge. This reading was announced while conducting the maneauver.

Figure 10 Showing Force Gague

2.2.2 Rudder Force Gauge

Rudder force gauge was used for the "VMC" test. The force transducer has metal clamp straps that are clipped on the lower portion of the aircraft rudder pedals. The test pilot flying shall adjust for comfort and apply leg force while conducting the maneuver. Force readings are shown with a hand-held terminal that is connected via wires. The crew shall read and record data from this device while test pilot flies the maneuver normally. The device was be secured and positioned to ensure no control interference occurs.

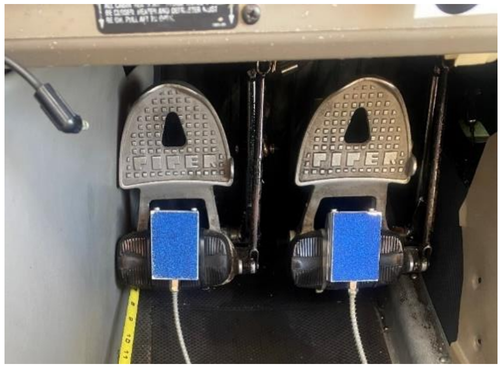

Figure 11 Showing Rudder Force Gagues on Piper Seminole

2.2.3 GoPro Cameras

The Piper Seminole that was tested, was supplied with two GoPro Cameras. These GoPro cameras were placed in close arrangement that the instrument panel of the aircraft was seen. The cameras also served as a backup with the data collection when data was relatively hard to be written down.

Figure 12 Showing GoPro Camera

2.2.4 Measuring Tape

Two measuring tapes were used to record the yoke position and the rudder position. Test pilot was the crew member reading and calling out the indications. Velcro was used to hold the tape in place during the flight.

Figure 13 Showing Measuring Tape Installed in Cockpit

2.3 Test Location

The aircraft shall take off and landed at Melbourne International airport (KMLB). The aircraft shall takeoff and fly southeast on the coast between Melbourne and Sebastian airports as well as west of Valkaria. All maneuvers were conducted above 3000 feet AGL. Figure shows the area where the data collection occurred. The local weather conditions, also known as METARs, for the flight were recorded from the Automatic Terminal Informaniton System (ATIS) at Melbourne at the time.

Test 1 Weather:

20/03/2022 20:53Z-> METAR KMLB 202053Z 03012KT 10SM CLR 22/13 A3014 RMK AO2 SLP204 T02220128 56010

20/03/2022 19:53Z-> METAR KMLB 201953Z 04014KT 10SM CLR 23/14 A3015RMK AO2 SLP207 T02330144

20/03/2022 18:53Z-> METAR KMLB 201853Z AUTO 01012KT 10SM FEW045 SCT085 23/16 A3015 RMK AO2 SLP210 T02330156

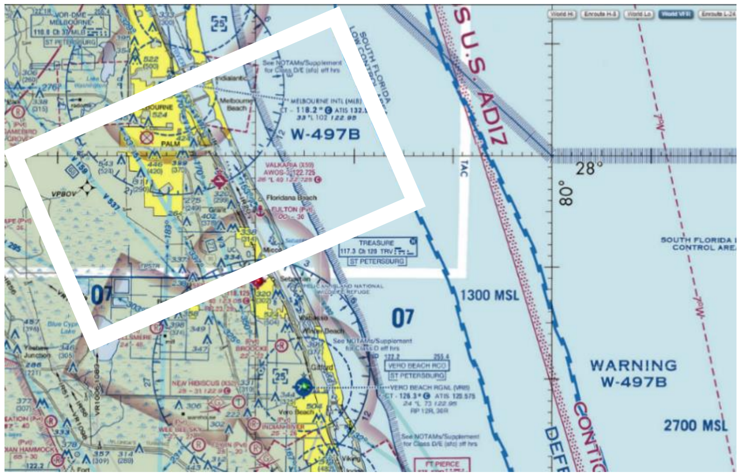

Figure 14 Showing Flight Test Location

2.4 Maneauvers

2.4.1 Longitudinal Static Stability

Longitudinal Static Stability flight can be used to locate the Neutral Points for the Piper Seminole aircraft. The Neutral Point is where the aircraft is neutrally stable. If the CG goes aft of this, the aircraft will become unstable no matter what input a pilot makes. The two stabilities observed for the Piper Seminole are stick-free and stick force stabilities. Stick-free is associated with finding the force required, while stick-fixed finds the elevator deflection needed for stability.

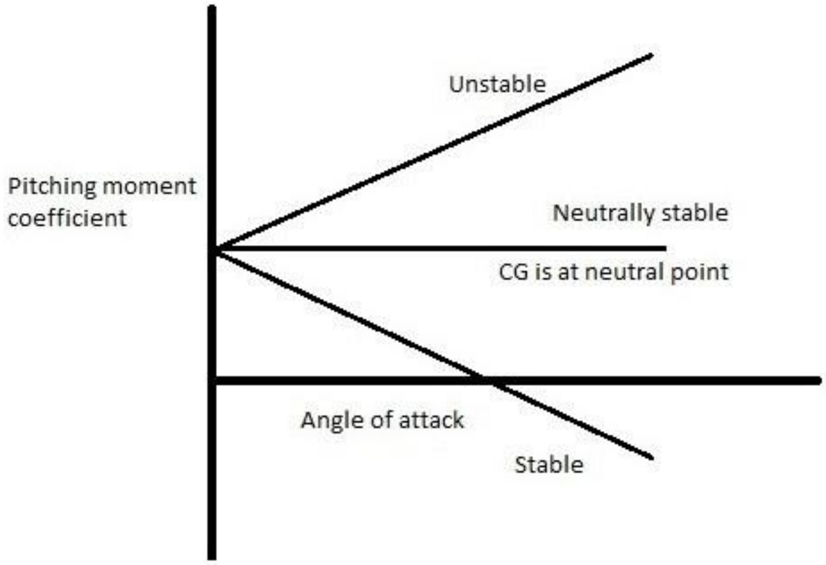

Figure 15 Showing Static Stability Effects

Procedure

1. Trim aircraft for proper phase of flight.
2. Increase or decrease airspeed by using longitudinal control without re-trimming the aircraft and the new value of airspeed is held constant by exerting a force upon the longitudinal control.
3. Record data at airspeed.
4. Repeat Procedure at an airspeed on the opposite side of the trim airspeed.
5. Alternate above and below the trim airspeed at airspeeds 5 to 10 knots.

Converthig the indicated airspeed to calibrared airspeed was achieved by using the chart from the PA-44-180 Pilot Information Manual.

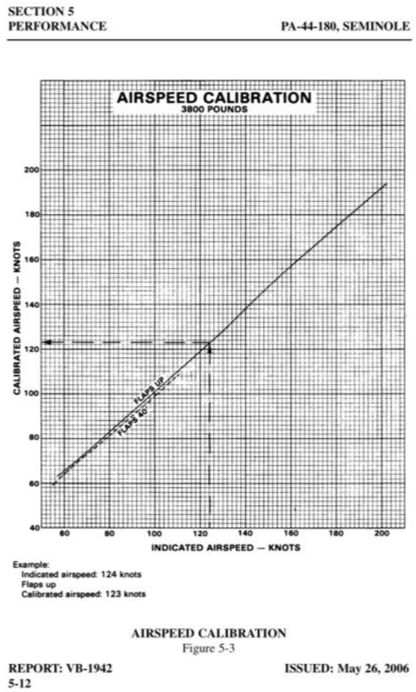

Figure 16 Showing Airspeed Calibration Chart for Piper Seminole

2.4.2 Longitudinal Dynamic Stability

This maneauver provides the results of a flight experiment, which was to find the long period Phugoid at different CG's. The damped frequency and the natural frequency were found for the flight conducted. This should be done by using both AFT and FWD CG's. The phugoid is the continuous up and downwards movement of the aircraft. The damping can be calculated either using a equation or using a half cycle plot. For this test, the half cycle plot shall be used.

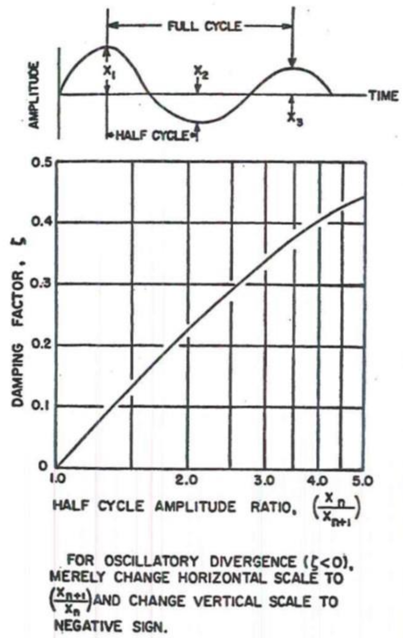

Figure 17 Showing Half Cycle Plot used for Data Reduction

The dampning frequency and natural frequency can then be found. These values will be used to determine if the aircraft is dynanically stable.

$$\text{Damped Frequency} = \frac{2\pi}{\text{Period}}$$

$$\text{Natural Frequency} = \frac{\text{Damped Frequency}}{(1 - \text{Damping Factor}^\wedge 2)\ ^\wedge\ .5}$$

The data below shows an example of how the maneuver can be analyzed and receive value.

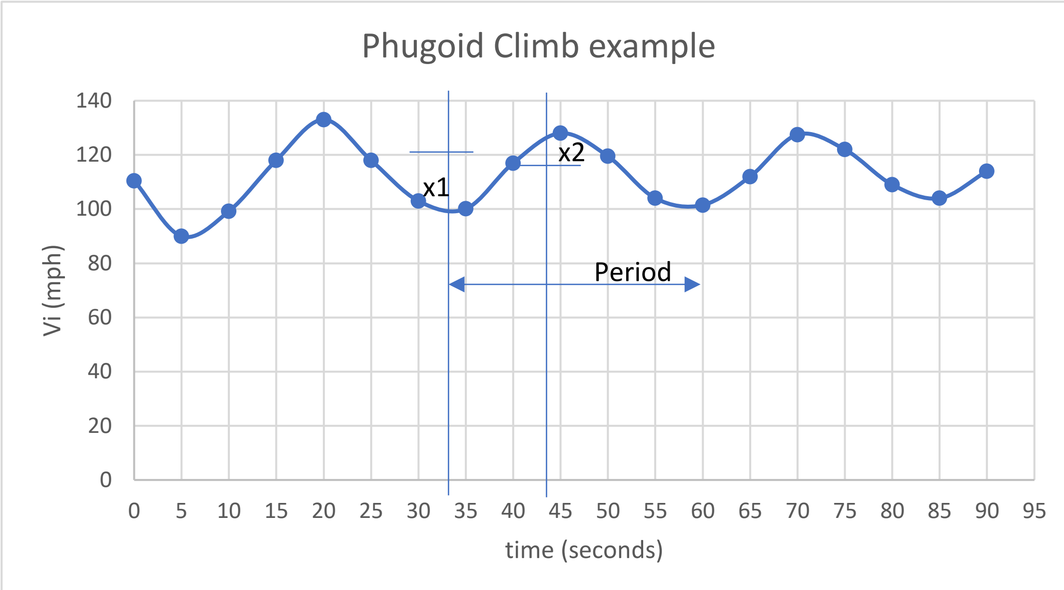

Figure 18 Showing Phugoid Climb Example

Table 2 Showing Longitudinal Dynamic Stability Example Results

Configuration	Period(s)	X1 at 35 (s)	X2 at 45 (s)	Damping ratio	Damped Frequency (rad/s)	Natural Frequency (rad/s)
Climb	25	15	13	0.05	0.2512	0.2595

Procedure

1. Longitudinal Dynamic Stability Procedure Trim airplane (record fuel consumed and power setting)
2. Using only elevator control, reduce airspeed 10 to 15 mph
3. Let go and observe
4. Record airspeed, pressure altitude, and pitch attitude over time (every 5 seconds)

2.4.3 Static and Dynamic Lateral-Directional Stability

This maneuver demonstrated and analyzed the lateral-directional stability of the Piper Seminole aircraft. This is important especially when aircraft are landing in windy conditions. Steady heading sideslips are used to measure this, as side slip is a factor of both lateral and directional stability. Directional stability is essentially that of maintaining zero sideslips.

Dutch roll is the combination of yaw and roll movement. This is prevented during the level cruise so that unnecessary aircraft movement is not induced and the aircraft remains controllable. Larger aircraft would have a system called a “yaw damper” to reduce the effects of a dutch roll. Most GA multi-engine aircraft do not have this system, thus relying on pilot input and aircraft design to maintain this stability.

According to FAR 23.181 Dynamic Stability (old FAR), “the airplane must be damped to 1/10 amplitude in 7 cycles with the primary controls.” This shall be used to analyze the stability of the Piper Seminole. The damping ratio can be found from the Dutch Roll time history using the half-cycle amplitude ratio. The undamped natural frequency W_{NDR} can be determined using the damped natural frequency W_{DDR} and the damping ratio.

Procedure – Spiral Mode

Record the following data once the airplane is trimmed:

1. Read data once aircraft is trimmed at cruise.
2. While yoke is kept in neutral position 5 degree bank is conducted using rudder.
3. Record data at 5 degrees of the bank.
4. Rudder is then returned to the trim position, then all controls are gradually released.
5. Aircraft spiral mode is then observed. Data is then recorded every 5 seconds for 30 seconds.

Procedure - Dutch Roll

1. Read and record values once aircraft trimmed

2. Conduct rudder doublet

3. Release controls gradually to see response

4. Bank angle and heading are also recorded via video

2.4.4 VMC Test

As stated, a large number of variables exist with VMC. The data retrieved from the flight test are mainly interpolated because it is deadly to fly close to VMC. For the test flight, rudder deflection can be found during engine failures. Plots of rudder deflection vs speed can be created at different altitudes. The VMCs at the different altitudes are then further interpolated to get VMC at sea level. CG data can also be compared. VMC for the Seminole is 56 KIAS. This shall be compared with the calculated VMC from the flight test. Max rudder deflection for the Piper Seminole is 37 degrees left and right. This was used as the intercept for calculations. Rudder force were also recorded when conducting the manueauver.

Procedure

1. Trim aircraft for cruise setting at planned altitude
2. Fail an engine by pulling back on the controls.
3. Airspeed is decreased while holding heading and altitude, data is then recorded.
4. Data is recorded after noticeable control movement by pilot or decrease in 5 knots, which ever comes first.
5. Aircraft shall not decelerate under 80 KIAS (per FIT Aviation requirement)

Chapter 3 Results and Analysis

Results

3.1.1 Longitudinal Static Stability

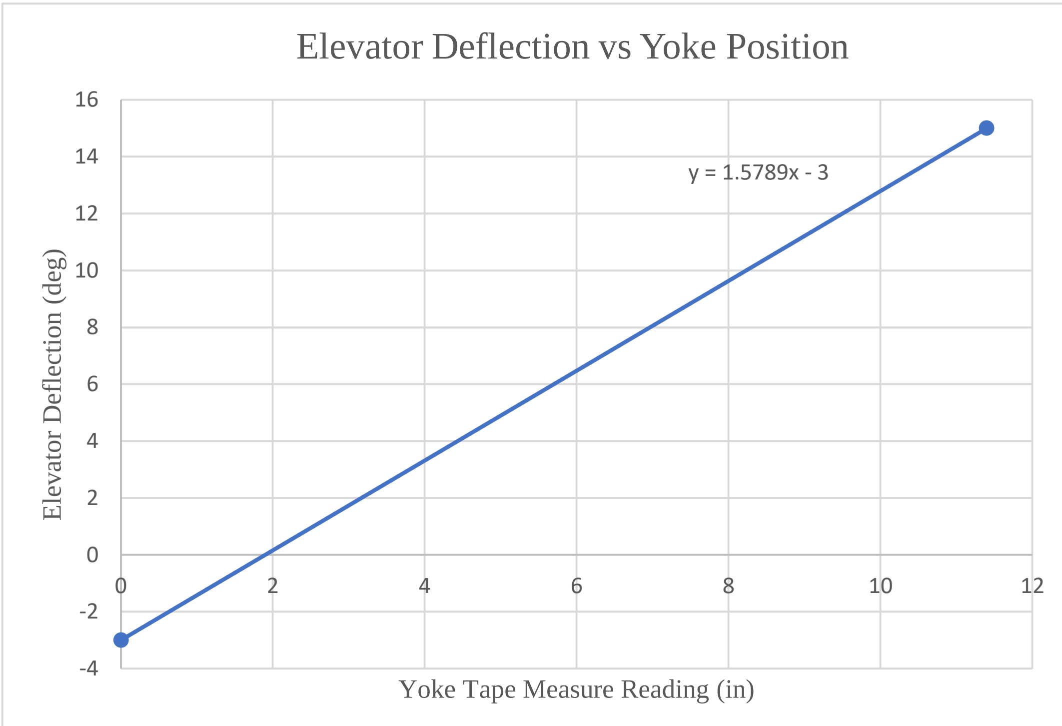

Figure 19 Showing Elevator Deflection vs Yoke Position

Most fwd and aft position of tape measure using the yoke was recorded and graphed. Max down deflection was -3 degrees while the max up defection is15 degrees.

Table 3 Showing Trim Speeds

Climb Trim	Cruise Trim	Descent Trim
105	115	120

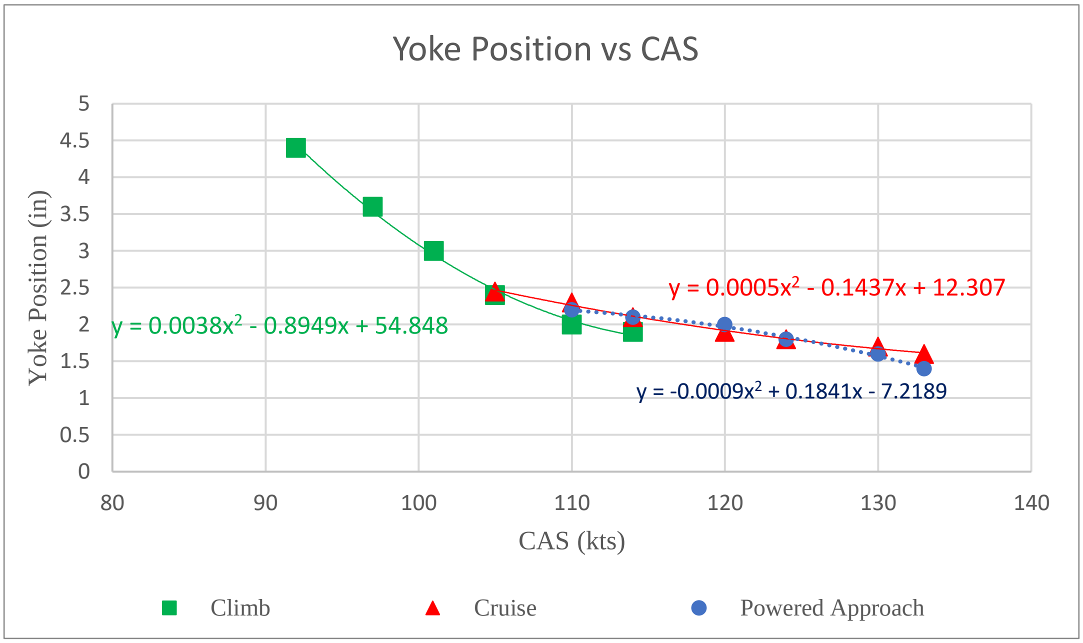

Figure 20 Showing Yoke Position vs CAS

Plot above shows yoke position vs CAS. For both climb, cruise and powered approach, the lower the airspeed the greater the yoke position will be. The faster airspeeds for all flight configurations shows the yoke position leveling off.

Climb required greater displacement than cruise and powered approach. It also go into consideration that the lower the starting or trim speed is, the greater deflection required. This is because less airflow is flowing around the aircraft. This means the aircraft has to deflect it surfaces more to make up the reletivly lower air traveling around.

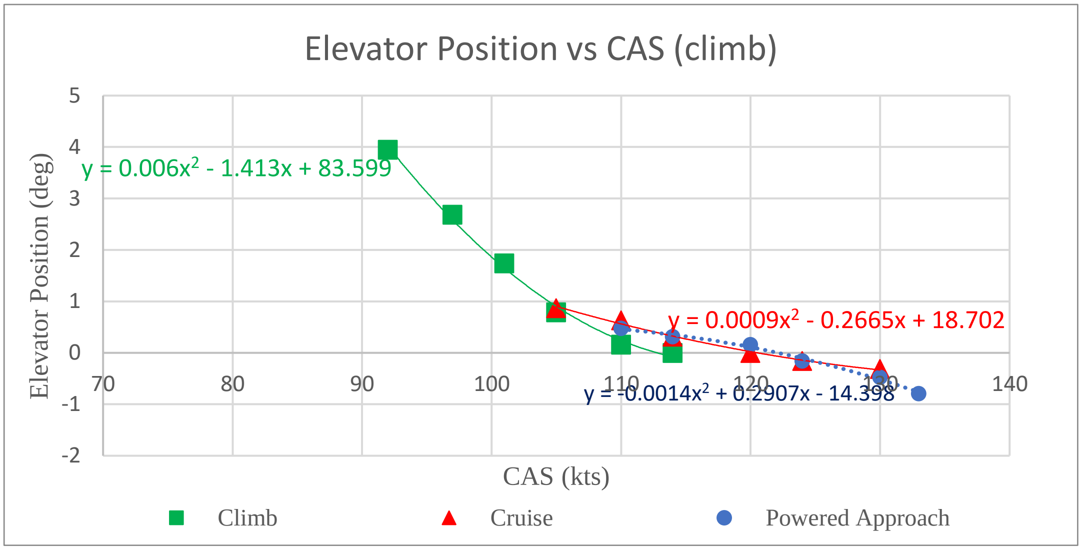

Figure 21 Showing Elevator Postion vs CAS

Plot above shows elevator position vs CAS. Using the equation generated by the max fwd and aft rudder deflection, the elevator position was found. Although for this plot, the elevator position is used, the same trend and analysis applies.

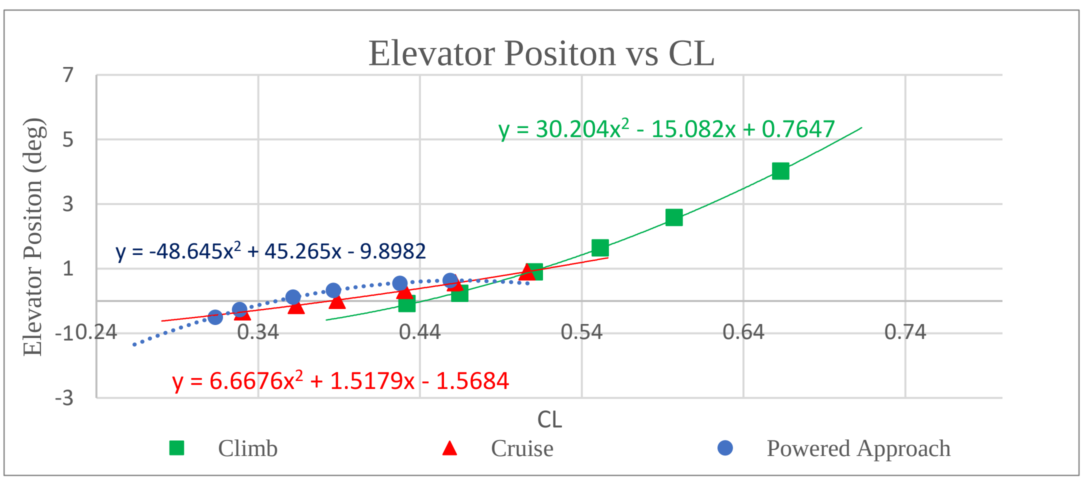

Figure 22 showing Elevator Position vs CL

Figure 22 shows the elevator positon vs CL. The plots all show that the greater the coefficient of lift, the greater the elevator position. This is because the aircraft is likely at a greater angle of attack with a higher elevator positon at a constant airspeed. The greater the AOA is, the more lift an aircraft will produce. Lift generated by the aircraft is also greater at faster airspeeds. Data points with higher airpseeds due to forcing the elevator downwards will have a higher CL.

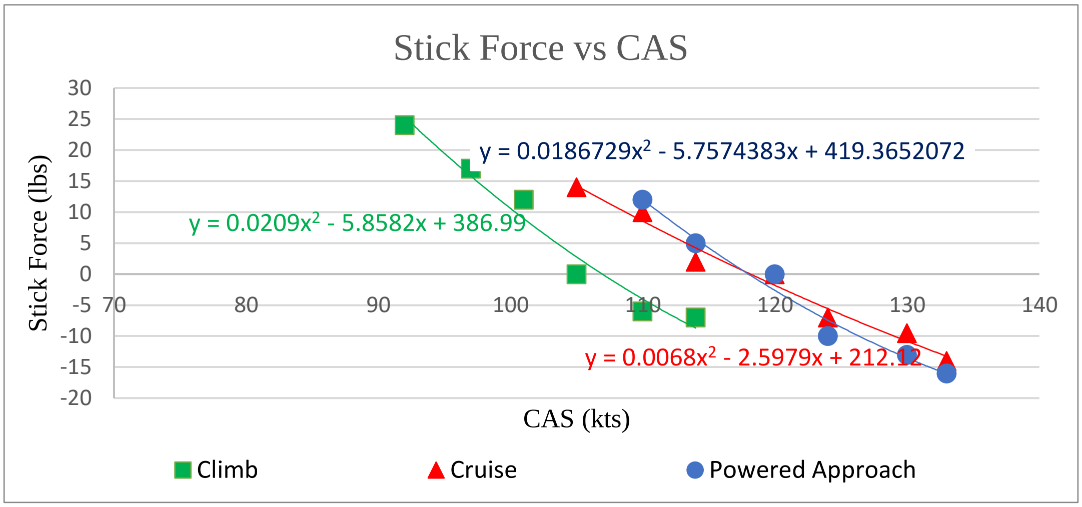

Figure 23 Showing Stick Force vs CAS

Figure 23 shows the stick force vs CAS. The plot shows for climb, cruise and powered approach, the lower the airspeeds are, the greater the force needed to hold the positions. The same analysis can be drawn from the stick-fixed data. Less airflow flowing over the aircraft, thus requiring greater force imput by the pilots to maintain the flight configuations at slower speeds.

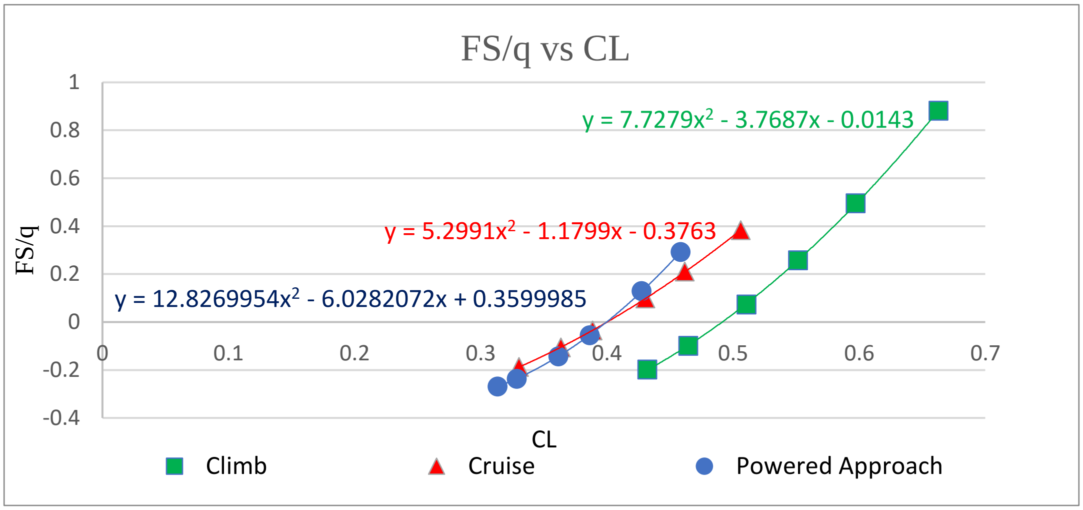

Figure 24 Showing FS/q vs CL

Plot above shows factoring the dynamic pressure to the force vs the coefficient of lift. The same analysis and trend can be drawn from this plot like the elevator position vs CL. The more force applied to the controls in terms of longitudinal stability, the greater the lift the aircraft is able to produce due to the control surfaces deflecting.

3.1.2 Longitudinal Dynamic Stability

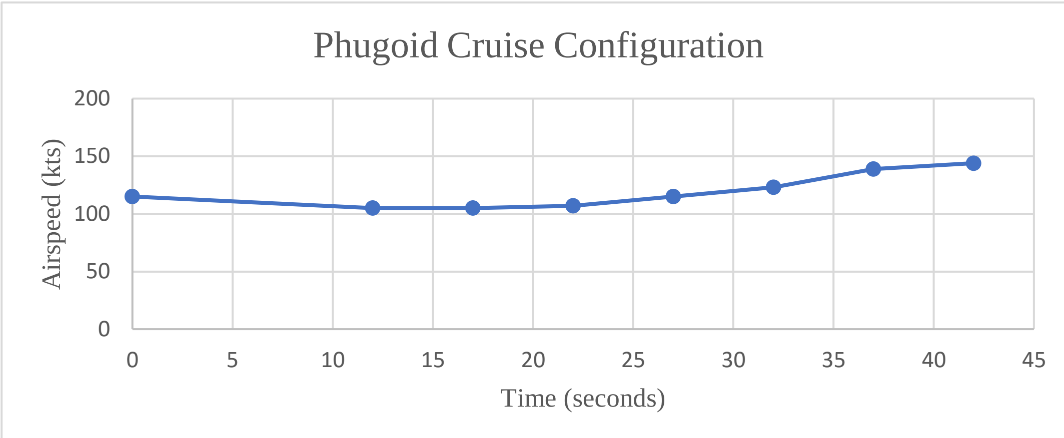

Figure 25 Showing Phugoid Results for Cruise

Table 4 showing phugoid results

Configuration	Period(s)	Damping ratio	Damped Frequency (rad/s)	Natural Frequency (rad/s)
Climb	undef	undef	undef	undef

The result for the above plot shows a constant cycle on the plot. Highest airspeed was 142 kts. This test went on for about 42 seconds. Aircraft airspeed did little to no decreasing after 10 seconds into the test. An expected phugoid mode was not show. During the maneuver, the aircraft bank kept on increasing to the right, thus allowing the aircraft to lose its vertical component of lift generated. Gravity then contrubited to increasing the airspeed as the aircraft descends. The trim configuration was not properly configured, thus causing the unexpected results. However, the aircraft was not unstable and was easily able to be controlled by the pilot during and after the test maneauver.

“23.181 (d) … Any long-period oscillation of flight path, phugoid oscillation, that results must not be so unstable at to increase the pilot's workload or otherwise endanger the airplane.”. The right banking turn barly increased the test pilot’s work load, as a very easy left control imput corrected the bank. The aircraft was not in danager during the maneaver as well. With that being said, according to FAR 23.181 (d), the piper semenole was longitudinal dynamically stable.

3.1.3 Static and Dynamic Lateral-Directional Stability

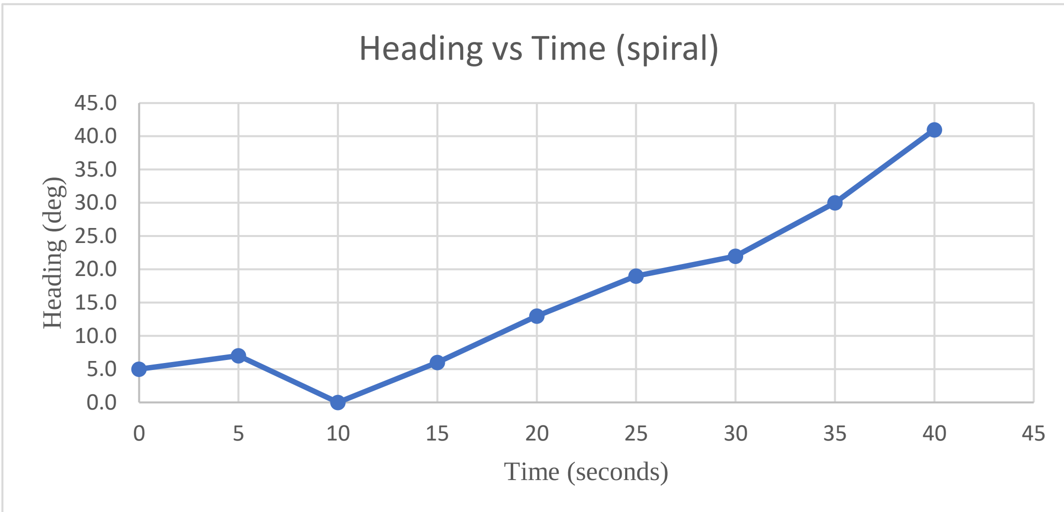

Figure 26 Showing Heading vs Time during Spiral

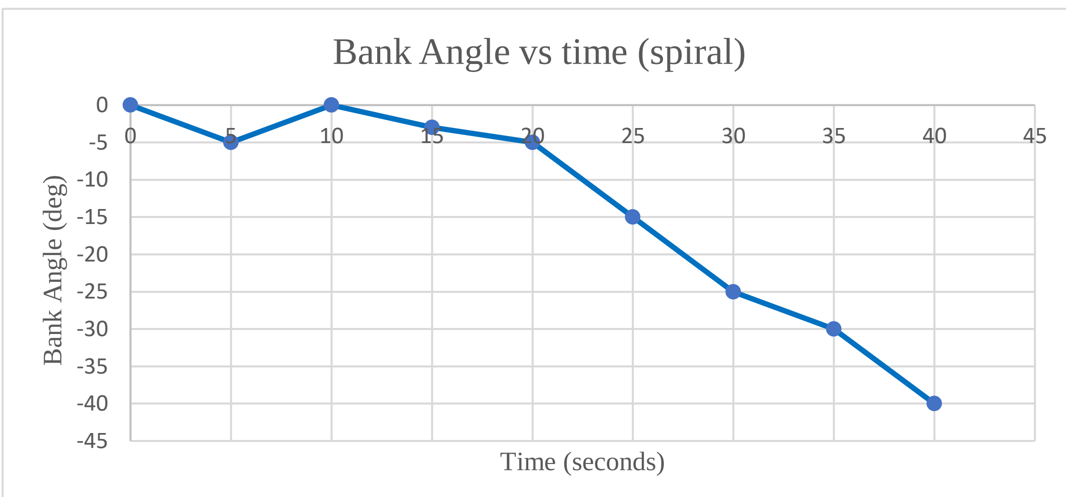

Figure 27 Showing Bank Angle vs Time during Spiral

Graphs above shows heading and bank ange vs time during the spiral mode test. Over time, the aircraft kept on increasing its heading and bank angle, thus showing a diversion from stability. This was due to the incorrect neutral trim experienced as well. It is more evident with these results that the aircraft started to spiral to the right after 15 seconds.

Although the aircraft bank kept on increasing, the Piper Seminoledid stabilize and showed positive stability for the first 15 seconds. The aircraft also showed no difficulties recovering or increasing the workload while flying. 15 seconds is enough time for a pilot to recover on their own and experience the stability characteristics of the aircraft. Because the aircraft was able to return to neutral position within 15 seconds, the aircraft is stable when conducting the spiral mode.

Dutch roll videoed by crew member in back seat. The results showed the aircraft stabilized after 3 cycles in 9 seconds. This means the period will be 3 seconds. If the damping ratio was set to a value of 0.1, then the table below privides the damped frequency and natural frequency.

Table 5 Showing Dutch Roll Results

Period(s)	Damping ratio (est)	Damped Frequency (rad/s)	Natural Frequency (rad/s)
3	0.1	2.09	2.1

23.181 (b) states “Any combined lateral-directional oscillations ("Dutch roll") … airplane must be damped to amplitude in 7 cycles with the primary controls”. Based on these results, the aircraft is lateral-directional positive stable, as the damping occurred around 3 cycles.

3.1.4 VMC Test

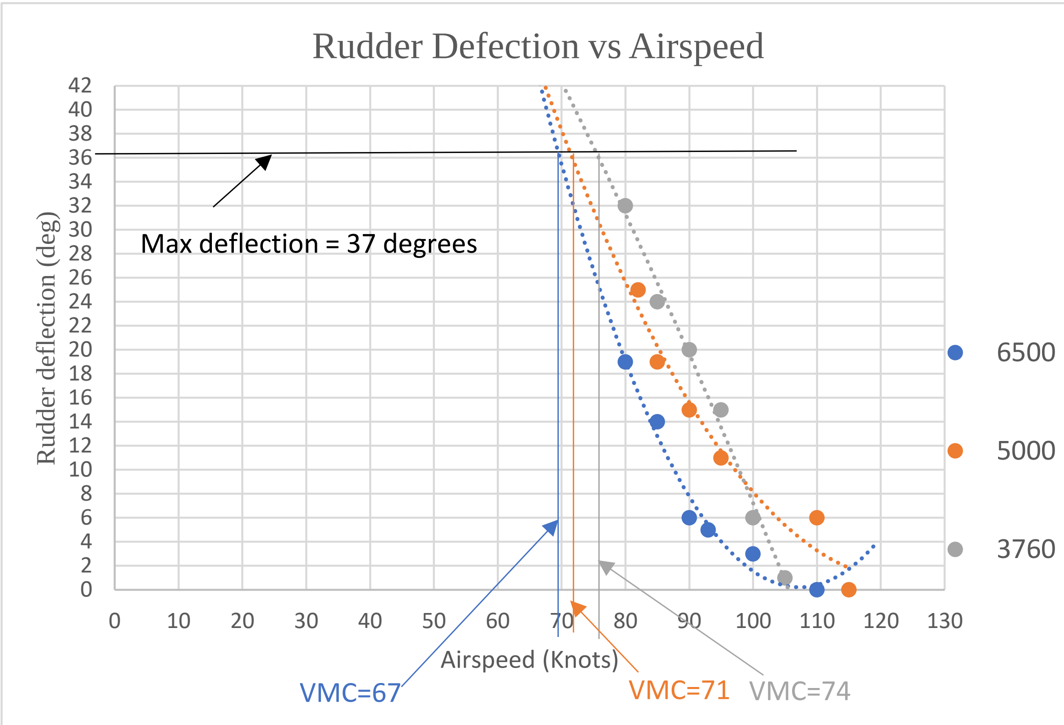

Figure 28 Showing Rudder Deflection vs Airspeed from VMC Test

The plot above shows rudder deflection vs airspeed at 6500 feet, 5000 feet and 3760 feet. Using the trend up the the max rudder deflection, the VMC at the different alttudes were found. At 6500 feet, VMC was 67 KIAS. At 5000 feet, VMC was 71 KIAS. At 3760 feet, VMC was 74 KIAS.

The results shows that the higher the altitude, the lower VMC will be. This is because the higher the altitude, the lower the pressure will be. The lower pressure has less air particles for the operating engine to provide power. This means the force the pilot has to imput to combact the one engine force is less.

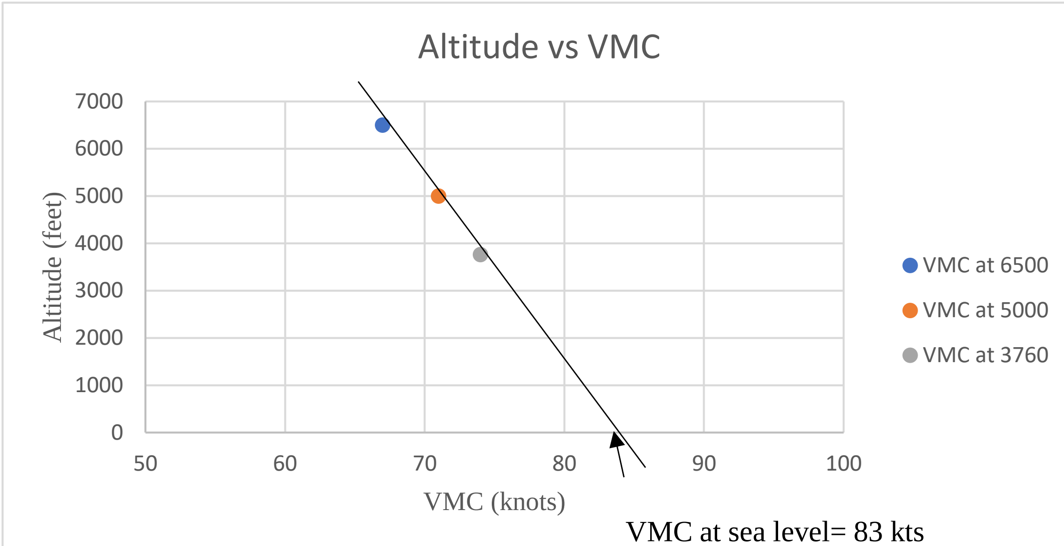

Figure 29 Showing Altitude vs VMC

The VMC altitudes were then used to find VMC at sea level. The graph shows that VMC at sea level is at 83 knots. Piper published VMC for the piper semenole to be 56 knots. There is a 42% increase of the VMC from the flight test. VMC has other conditions and configurations that can change its value. Every day when the weather changes, the values also changes as well. More test can be done to gather more data at different configurations.

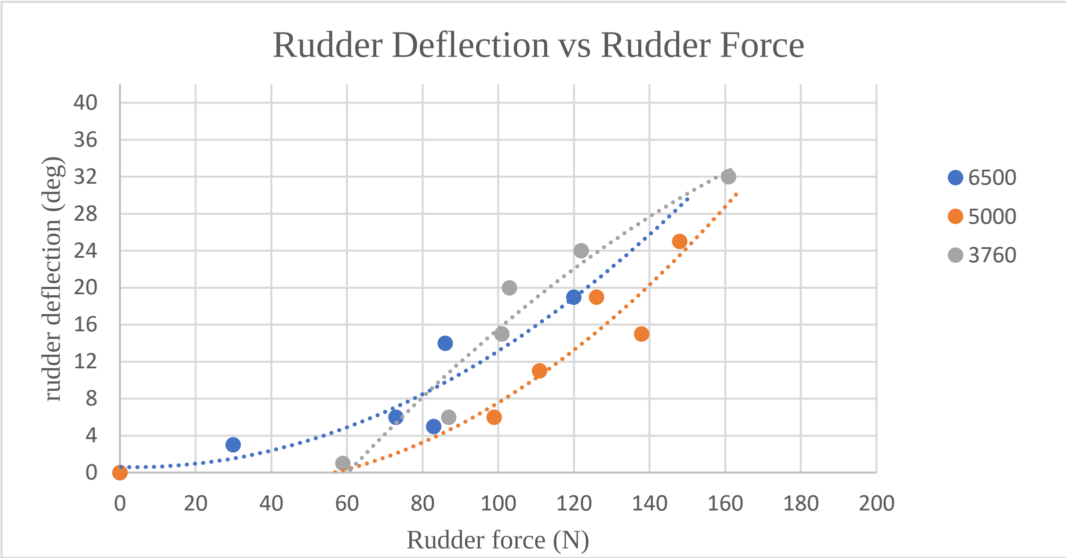

Figure 30 Showing Rudder Delfection vs Rudder Force

Plot above shows Rudder Deflection vs Rudder Force. The rudder force at the lowest altitude, 3760 feet, was greater than the higher altitudes. Only one point was greater than 150N of rudder force at the lowest altitude. All other points satisfied the requirement of being less than 150N of rudder force applied by the test pilot. The Aircraft was dynamically stable when immediately conducting the simulated engine failure. It was fairly easy to stabilized the aircraft after the simulated engine failure. The aircraft was also stable statically while maintaining a straight track. No abnormanl controls had to be inputted once the test began.

Chapter 4 Conclusion & Limitations

Conclusion

This thesis examined the Piper Seminole controllability and stability characteristics. Only one flight was able to be conducted during the scope of the thesis. More flights and data collection would have made the findings more conclusive. However, based on the conditions and flights conducted, I can say the aircraft was capable of meeting CFR 23 flight stability requirements.

Because only one flight was conducted, I was not able to find the neutral point while doing the longitudinal stability test. More than one CG is needed in order to make conclusions and data analysis and, given the conditions, impossible to be conducted during one flight. Other data was not able to be analyzed and compared due to conducting one flight.

Some of the data showed signs of the aircraft continuing to a bank to the right without pilot input. The rudder trim was in the neutral position, but that configuration was not neutral for the aircraft during flight. This caused a progressing right bank during the ending of maneuvers. Looking back at the video, I saw myself sometimes adding left aileron correction at different phases of flight. For a future test, the trim point shall be left for a longer period in order to ensure the aircraft is straight and level. Although the engines are 180 hp based on the specifications, over time the number changes. It is likely one engine is producing less power than the other. If more tests have been conducted, this could have been analyzed further.

More flight test on multi-engine aircraft with counter-rotating propellers is recommended. The one flight did not provide enough data to analyze the counter-rotating propellers. I also would conduct more tests focusing on VMC. VMC has so many configurations and conditions that can change the value. Testing different configurations would have allowed more data collected and analyzed done on VMC.

Flight Testing results can also vary with how pilots interpret regulations and maneuvers to be conducted. Also, the flight experience of pilots and their testing exposure can add to the data collection impact. A different pilot conducting the maneuvers or a different crew recording the data can change the results greatly. I recommend having more than one day of practicing the plan of action of the flight, to ensure all crew members are completely certain of their tasks and jobs while in the aircraft.

Limitations

Throughout this thesis, there have been numerous limitations encountered. Given all the conditions and requirements for the flight, everything was done to the best of my abilities in order to gather the most accurate data possible. Weather conditions were fairly good, but less windy conditions while conducting testing would have made data collection better.

Only one flight was conducted because prior approval was needed in order to conduct testing on the Piper Seminole. Due to insurance liabilities and the risk of using a multi-engine aircraft, they are almost impossible to rent. Having options of renting the piper Seminole from different places was even a greater challenge, as not everyone owned these aircraft. In the end, the request was successfully approved. Bad weather, aircraft in maintenance, and fitting in the schedule were obstacles that had to be overcome.

Using transducers was not approved to be installed on the aircraft. This meant data for sideslip, rudder deflection and elevator deflection were used by comparing cockpit control surfaces vs outside aircraft deflection. More data could have been analyzed if more data computerizations were available. Test pilot flying was also a part of data collection due to less computerized recording. This increased the workload, yet all data was successfully recoded. The best fwd CG was unable to be obtained due to needing a person in the back to help with the data recording. Regardless of all these limitations, the data needed to make a conclusion was sufficient.

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[1] Kimberlin, Ralph D., Fligth Test of Fixed-Wing Aircraft, AIAA Education Series, 2003

[2] Federal Aviation Administration (2008). Flying Light Twins Safely. *FAA-P-8740-66*

[3] Federal Aviation Administration. Pilot's Handbook of Aeronautical Knowledge. U.S. Dept. of Transportation, Federal Aviation Administration, 2008

[4] Piper PA-44-180 Semenoile Pilot Operationg Handbook (POH)

[5] Electric Code of Federal Regulations, Title 14, Chapter 1, Subchaprer C, Part 23, Sec. 23.181

[6] Electric Code of Federal Regulations, Title 14, Chapter 1, Subchaprer C, Part 23, Sec. 23.175

[7] Electric Code of Federal Regulations, Title 14, Chapter 1, Subchaprer B, Part 23, Sec. 25.149

[8] Electric Code of Federal Regulations, Title 14, Chapter 1, Subchaprer B, Part 25, Sec. 25.173

Appendix: Collected Data

Table 6 Showing Longitudinal Static Stability Climb

A/C		Semenole	Tail #	N880FT						
Fuel Load (gallons)		80	Gross Weight	3523	CG	89.03		burn per hour	23.4g	
Engine Start Time		14:23	Takeoff Time	14:38	Landing Time	16:03				85 minutes flight time in air
Engine Shut off Time		16:10			Shutt off fuel	46		total flight burn	34G	1.8 hobs total
		Longitudinal Static Stability Climb								
Current Time		Airspeed(KIAS)	Stick force(lbs)	Stick force(lbs)	Yoke Position (in)	Yoke position (in)	Elevator Positonn (Positoin est)	altitude (ft)	OAT	RPM
47:50:00		105	0	0	-2.4	2.4	2.8	4140	14	25
48:32:00		100	-12	12	-3	3	3.4	4700	14	25
49:39:00		110	6	-6	-2	2	2.4	5100	14	25
50:43:00		95	-17	17	-3.6	3.6	4	5860	14	25
51:34:00		115	7	-7	-1.9	1.9	2.3	6060	14	25
52:27:00		90	-24	24	-4.4	4.4	4.8	6780	14	25

Table 7 Showing Longitudinal Static Stability Cruise

Current Time	Airspeed(KIAS)	Stick force(lbs)	Stick force(lbs)	Yoke Position (in)	Yoke position (in)	Elevator Positonn (Positoin est)	altitude (ft)
47:50:00	120	0	0	1.9	-1.9	-1.5	4140
48:32:00	115	2	2	2.1	-2.1	-1.7	4700
49:39:00	125	7	-7	1.8	-1.8	-1.4	5100
50:43:00	110	10	10	2.3	-2.3	-1.9	5860
51:34:00	130	9.5	-9.5	1.7	-1.7	-1.3	6060
52:27:00	105	14	14	2.45	-2.45	-2.05	6780

Table 8 Showing Longitudinal Static Stability Powered Approach

Airspeed(KIAS)	Stick force(lbs)	Stick force(lbs)	elevator position (deg)	Elevator Positonn (in)
115	0	0	1.7	-1.7
103	7	-7	2	-2
125	-7	7	1.5	-1.5
90	8.5	-8.5	2.6	-2.6
135	-11	11	1.1	-1.1
64	16	-16	3.3	-3.3
120	-18.5	18.5	1.5	-1.5

Table 9 Showing Phugoid Results

Time(seconds)	Airspeed(kts)	altitude (ft)	Stick force(lbs)	yoke position(in)
0	115	5040	0	2
12	105	5340	1.5	2.15
17	105	5440	2	2
22	107	5480	5	2
27	115	5460	5.2	2
32	123	5400	7	2
37	139	5340	10	2
42	144	5280	11.5	2.1

Table 10 Showing Spiral Mode Results

Airspeed	altutde	bank angl e	heading	sideslip	rudder positoin
113	5200	0	5.0	0	0.0
114	5200.00	-5	7	0	8.5
114	5200.0	0	0.0	0	8.0
115	5200.00	-3	6	0	8.0
116	5200.00	-5	13	0	8.0
117	5200.00	-15	19	0	8.0
121	5200	-25	22	0	8.0
124	5100	-30	30	0	8.0
134	5000	-40	41	0	8.0

Table 11 Showing VMC Results

airspeed (KIAS)	Altitude (feet)	heading (deg)	rudder Position (in)	rudder force (N)	sideslip (deg)	bank angle (deg)	Rudder Deflection(in)
6500 Feet							
110	6500	102	8.0	0	15	0	0
100	6450	104.00	8.2	30	8		3
93	6400	104.00	8.4	83.0	0		5
90	6400	100.0	8.4	73	0		6
85	6400	99.00	8.8	86	0		14
80	6400	102.00	9.1	120	0		19
5000 Feet							
115	5200	277	8	0	0	2.0	0
110	4000	272	8.4	99	20	2.0	6
95	4580	277	8.6	111	0	1.0	11
90	4380	276	8.8	138	0	2.0	15
85	4200	282	9	126	0	2.0	19
82	4100	272	9.3	148	0	2.0	25
3760 feet							
105	4200	2	8.2	59	20	3	1
100	4000	2	8.4	87	20	2	6
95	3760	4	8.8	101	20	2	15
90	3760	4	9	103	20	2	20
85	3360	5	9.3	122	20	3	24
80	3320	4	9.70	161	20	3	32